Data Collection Ltd.

ROMDAS for Windows User's Guide

14 June 2004

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1.3	14 /3/04		Laser Profiler
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1 Introduction

1.1 Introduction

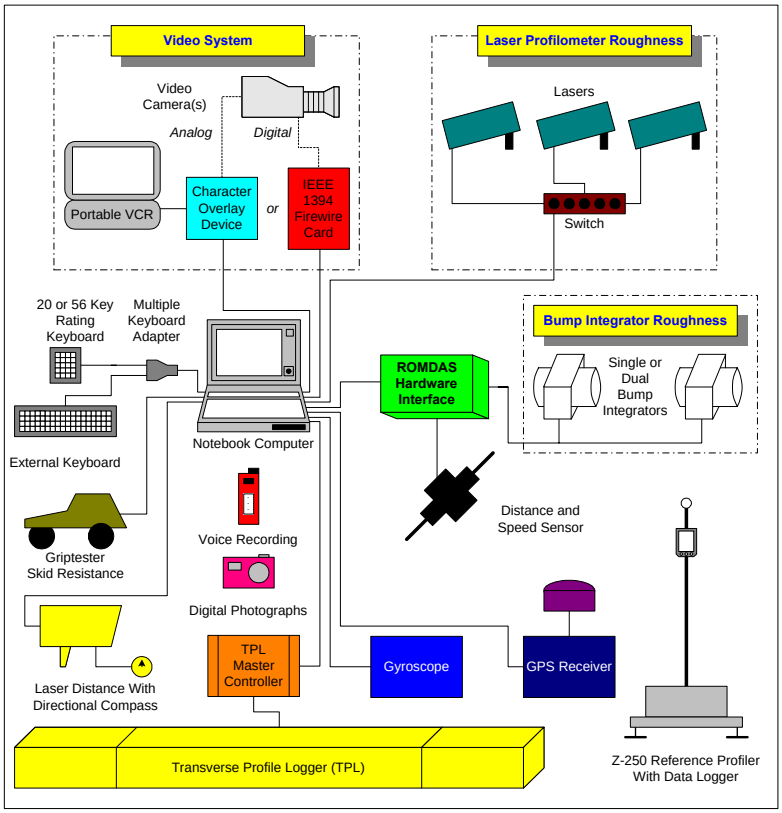
Overview

The "ROad Measurement Data Acquisition System" (ROMDAS) has been developed by Data Collection Ltd. (DCL) as a generic system for collecting data on road condition and travel time.

It is possible to use ROMDAS for:

- roughness surveys;
- travel time and congestion surveys;
- condition rating surveys;
- inventory surveys;
- moving traffic surveys;
- transverse profile/rutting surveys;
- video log surveys;
- recording the location of digital photographs;
- creating voice records which are associated with road attributes;
- collecting global positioning system (GPS) data;
- collecting skid resistance data using the Findlay Irvine GripTester;
- as a digital trip meter.

ROMDAS uses a personal computer to store all the data and to interact with the instruments.



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Components

The basic ROMDAS system consists of:

- a hardware interface;
- a digital distance/speed sensor which is spliced into the vehicle speedometer cable or attached to an electronic speedometer;
- all necessary electrical plugs/sockets and cabling;
- software.

The optional instruments are used to collect additional data.

The hardware interface connects to a sensor on the roughness meter and to the distance/speed sensor. During the survey, the interface monitors both the distance/speed sensor and the roughness meter. At the end of the survey the data are processed into Microsoft Access database files.

The only permanent fixture in the vehicle is the distance/speed sensor. It is therefore practical to move ROMDAS between vehicles as long as they are fitted with a distance/speed sensor and harness. Since ROMDAS uses a portable computer as the data logger, the computer may also be used for other activities in between surveys.

Vehicles

ROMDAS can be used in any type of vehicle, from passenger cars through vans to four wheel drives or trucks. The photos below show vehicles used for ROMDAS surveys in New Zealand and Malaysia. The ROMDAS web site at www.ROMDAS.com has additional photographs.

New Zealand

Malaysia

1.2 Types of Data Collected

Overview

Designed to be a portable and modular system, ROMDAS can be used to collect a range of data. It is common to start off with a basic system and then to enhance it with additional measurement instruments as survey needs become more sophisticated.

Roughness – Response Meter

A response-type roughness meter can be added to measure road roughness.

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ROMDAS will convert raw roughness data into calibrated roughnesses through user-supplied equations. If equations are available for different speeds, ROMDAS will apply the appropriate equation given the vehicle speed at the time of the measurement. This removes the constraint of trying to operate the vehicle at a single survey speed under all conditions.

If the only requirement is a simple roughness survey, ROMDAS can be run by the driver alone, eliminating the need for an additional operator. A single roughness meter can be used if the vehicle has a rear axle (half-car roughness); one or two roughness meters if independent rear suspension (quarter-car roughness).

Roughness – Laser Profiler

The ROMDAS Laser/Accelerometer System is an intelligent transducer specifically intended to measure road surface profile and optionally road texture characteristics. Distance from the surface under test to the transducer is measured by means of an infrared laser beam reflected from the surface onto a sensing element.

- For roughness the laser samples at 16kHz,
- The Laser is designed specifically for road measurement applications. The dynamic range is a large ± 128mm, important to prevent data clipping due to suspension movement.
- Triple high speed Analogue to Digital Converters are used with high 16-bit resolution.
- There is no skew between channels during sampling – channels are sampled simultaneously.
- Data is converted directly to digital data within the laser and remains digital throughout the processing stages, thus eliminating the problems of noise due to lengthy cable runs carrying analogue data. Data output is via Ethernet networking for easy connection of multiple lasers through standard Ethernet hub to computer running ROMDAS software
- Data all fully controlled from ROMDAS software so can be used simultaneously with other ROMDAS instruments like GPS, Video, and Rut Depth with TPL etc. Also only one calibration required for distance measurement instrument (DMI) for both Laser input and ROMDAS.
- Laser Safety features include - Mechanical shutter to isolate the laser beam - Keyed switch to power Laser - Configurable low speed cut-off to laser activation input

Visual Condition and Inventory

Condition and inventory surveys can be done using the computer keyboard. It is possible to assign any key to an event and these are recorded as point and continuous events. Using a special adapter available from DCL it is possible to connect multiple keyboards to the notebook computer. This makes it possible to have several observers performing rating at the same time—for example one doing condition and a second inventory. There is also a special 20 or 58 key rating keyboards that are ideal for condition surveys. Groups of keys can be assigned to an individual distresses or

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roadside events.

If it is necessary to establish the exact locations of certain attributes—for example km posts or signs—the ROMDAS Laser Surveyor option can be used. This sees a laser range finder with integrated compass and inclinometer used to establish the exact position of the attribute relative to the vehicle. If GPS is being recorded in the survey the geo-coordinates of the attribute can be determined with a high degree of accuracy.

Rut Depth

A 'Transverse Profile Logger' is available which can be used to measure the pavement transverse profile elevations using ultrasonics and to establish the rut depth. This instrument stores raw elevation data which are downloaded to the PC after the survey to calculate the rut depth under a user-definable straight edge. The transverse profile distortion is used to estimate potential causes of rutting.

Video Recording

A video camera can be used to record data on the pavement right-of-way or the surface. This is connected to a Firewire card. Survey chainages and other basic data are recorded to an overlay on the video image.

Multiple cameras can be used during the survey, for example to record the right-of-way as well as the roadside areas.

GPS Positions

When used with a GPS receiver, ROMDAS will record the global positioning data at user defined sampling intervals (> 0.1 s or 10Hz). A gyroscope can be fitted to estimate the location when there is a loss of satellite lock.

When used with most Trimble receivers, the ROMDAS for Windows software will store the survey data in files that can be directly differentially corrected.

Travel Time

Travel time and congestion surveys can be conducted using ROMDAS. These will give the travel time, distances travelled and acceleration on a second-by-second basis. The system has been specifically designed to collect data for use in the World Bank's HDM-4 congestion model.

Traffic Volume

ROMDAS can be used to perform 'moving traffic surveys'. These entail recording every vehicle that passes the survey vehicle. The data are used to establish and estimate the AADT.

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Skid Resistance

Skid resistance data can be collected using the GripTester produced by Findlay Irvine in Scotland[1]. ROMDAS stores the GripTester data and performs the same analyses as the original GripTester to determine the Grip and SCRIM numbers.

Digital Photographs

During ROMDAS surveys data can also be collected using a digital camera. Typically, this consists of photographs of roadside objects such as inventory items or km stones. The frame number corresponding to the image is entered to ROMDAS which associates a chainage with the photograph.

Voice Recordings

Voice messages can also be recorded. These are associated with a chainage in the same way as digital photographs. If the computer is equipped with a suitable sound card (most notebooks are suitable) they will be directly recorded during the survey otherwise a portable tape recorder is used.

1.3 ROMDAS Versions

Software Platforms

The ROMDAS software is available for two platforms:

- ROMDAS for Windows
- ROMDAS for MS-DOS

ROMDAS for DOS was the original ROMDAS software, developed in the early 1990s. It was superseded in 2002 by ROMDAS for Windows, which is described in this User's Guide. All development on ROMDAS for DOS ceased after the introduction of ROMDAS for Windows.

Hardware Interfaces

There are several versions of the ROMDAS Hardware Interface:

- Version 5.4 (2003 Onwards)
- Version 5.3 (2002 Onwards)
- Version 5 Hardware Interface (1999-2002)
- Version 4 Hardware Interface (1998-99)
- Version 3 Hardware Interface (Post-1996)
- Version 2 Hardware Interface (Pre-1996)
- Version 1 Hardware Prototype (1988)

ROMDAS for Windows only works with Version 5.3 and later. A replacement EPROM can be ordered.

[1] Findlay Irvine Ltd., Bog Road, Penicuik, Midlothian EH269BU, SCOTLAND. Phone: +44-1968-672-111; Fax: 44-1968-672-596.

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1.4 What Needs to be Done to Start Surveying?

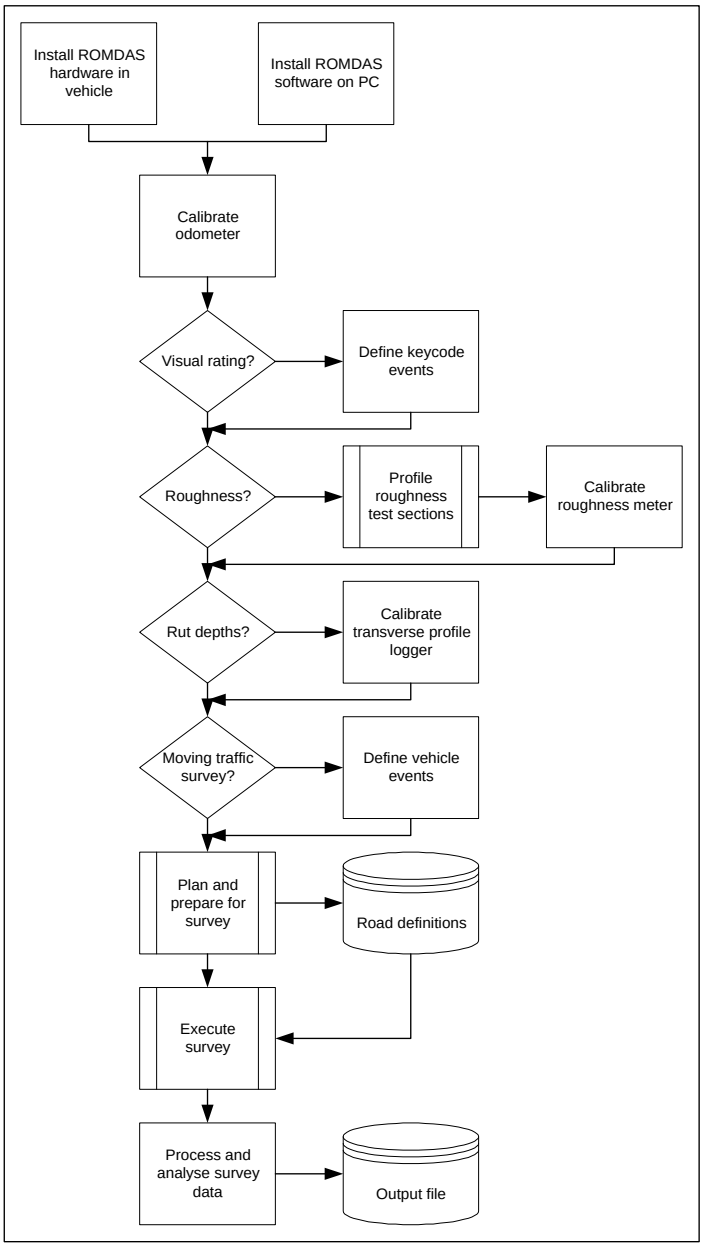
Read the Warranty and Software Licence

Before anything else read the Licence and Warranty details in Chapter 18. If you do not agree to these please return the ROMDAS equipment to DCL for a partial refund.

Overview of Process

As shown in the following figure, the following steps need to be done:

- Install the hardware and software
- Calibrate the instruments
- Plan and prepare for the survey
- Execute the survey
- Process the data



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Install the Software

Install and set up the ROMDAS software. This is described in Chapter 2

Install and Test the Hardware

The ROMDAS hardware needs to be installed in the vehicle and tested. This is described in Chapter 3.

Calibrate the Instruments

The calibration of the various instruments is described in Chapter 5 and the Appendixes to this manual.

Plan and Prepare for the Survey

This consists of route planning, establishing location reference points, *etc*. These are discussed in Chapters 4 and 6.

Do the Survey

The different surveys each have different data collection requirements. They are discussed in Chapters 7 through 13

Data Processing

The processing of survey data is described in the chapters on executing surveys.

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2 Installing and Running ROMDAS for Windows

2.1 Introduction

Protection

ROMDAS for Windows is copy protected. This sees a unique hardware fingerprint generated based on the name of the registered user and the hardware that it is installed to. This fingerprint is provided to DCL who will then provide a registration key which will ensure continued operation.

Without a registration key the software will work for an evaluation period of 30 days after which it will cease to operate. It is not possible to get around this by resetting the time or date on the machine or any other method. The software can be uninstalled and transferred to another machine, but this requires that a new registration key be issued.

2.2 ROMDAS CD

Starting the ROMDAS CD

The ROMDAS CD contains software and documentation for the ROMDAS, along with the other ROMDAS products available. Insert the CD and it should automatically start, displaying the menu below.

If the CD does not start automatically, do the following:

- Start Windows Explorer
- Locate the drive with the ROMDAS CD

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- Highlight the file **MenuEng.exe**
- Double click to start the menu.

ROMDAS Software

To locate the ROMDAS for Windows software:

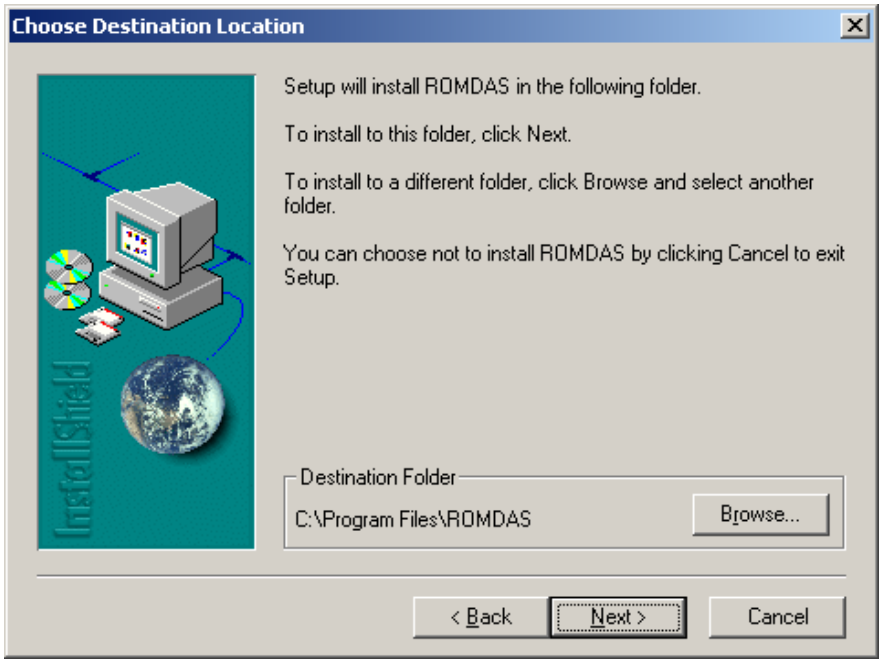
- Select **ROMDAS Road Measurement Data Acquisition System**
- Select **ROMDAS Software**
- Select **ROMDAS Windows Data Collection Software**

This will start the install.

2.3 Installing ROMDAS for Windows

Default Folder

The ROMDAS software is installed by default to the folder **c:\Program Files\ROMDAS**. If you would like to use a different folder select the **Browse** button when the next screen is displayed. Otherwise, select **Next** to run the install.


Choose Destination Location
Setup will install ROMDAS in the following folder.
To install to this folder, click Next.
To install to a different folder, click Browse and select another folder.
You can choose not to install ROMDAS by clicking Cancel to exit Setup.
InstallShield
Destination Folder
C:\Program Files\ROMDAS
Browse...
< Back
Next >
Cancel

Once installed, a shortcut will be placed on your desktop (see below).

2.4 Updating ROMDAS for Windows

Update Software

To update the ROMDAS software with a new version you should uninstall the old software before doing a full reinstall This is done by locating the **Remove Programs** icon and then highlighting the **ROMDAS for Windows** program to remove

The full reinstall is done using the same procedure as described in Section 2.3.

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2.5 Windows Settings

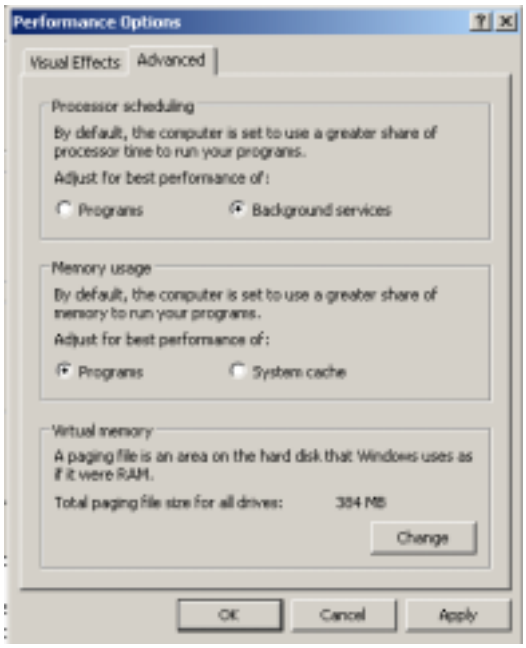
Power Saving Options and Screen Savers

All Windows Power saving options and screen savers should be turned off when using ROMDAS in data collection surveys.

Background Processing

The ROMDAS software uses Windows background services for the TPL, Video and Laser Profilometer devices. With Windows XP and Windows 2000 you can significantly increase the performance of ROMDAS if using any of these devices by changing the Processor Scheduling setting to "Background Services"

This option is set under: **Control Panel | System | Advanced | Performance Settings | Advanced | | Processor Scheduling.**


Performance Options
Visual Effects
Advanced
Processor scheduling
By default, the computer is set to use a greater share of processor time to run your programs.
Adjust for best performance of:
Programs
Background services
Memory usage
By default, the computer is set to use a greater share of memory to run your programs.
Adjust for best performance of:
Programs
System cache
Virtual memory
A paging file is an area on the hard disk that Windows uses as if it were RAM.
Total paging file size for all drives:
384 MB
Change
OK
Cancel
Apply

2.6 Evaluating and Registering ROMDAS

Evaluation Version

ROMDAS can be evaluated for a period of 30 days before registration is required. During the evaluation period the software is fully functional. However, after this period the software will no longer operate on the same computer except if you install a later version in which case another 30 days trial is available.

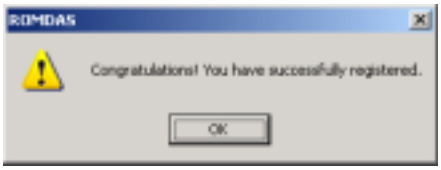
When the software is started in evaluation mode the screen below is shown. After a period of 5 seconds select **Start** and ROMDAS will continue to load.

Registering

Once the software has been purchased a registration key will be issued. Enter the name the software is to be registered to in the ROMDAS Registration window shown above (which can also be accessed from **About ROMDAS|Registration Status**) and select **Email Finger Print** or **Print Finger Print**. Both the user name and the fingerprint need to be supplied for the software to be registered. In the example above the fingerprint is EA6D-964E. Send the fingerprint to support@romdas.com or fax to number in the **Information|About ROMDAS** menu. E-mail will give the most prompt response.

The **Hardware Finger Print** is the unique hardware code for the computer that ROMDAS is to be installed to. Each fingerprint is unique to a single computer.

The user name and fingerprint is used to generate a unique registration key. This will be provided and should be entered as shown to the right. Once done the **Register** button is used to complete the process. If successful, the window below right will be shown. If not, please contact support@romdas.com.



NOTE: If you change the hardware on your computer the registration key may no longer work. It will be necessary to first obtain an uninstall key as described below for moving the software to a new computer, and then obtain a new key once the new hardware is installed.

Changing the Registration Key

The key is only valid for the specific machine hardware configuration so if ROMDAS is to be used on another computer or the hardware is changed, it will be necessary to uninstall the software and obtain a new key. The process is as follows.

- Start ROMDAS
- Select **Information|About ROMDAS|Registration Status**
- Select the **Unregister ROMDAS** button

ROMDAS will shut down and the window below will be shown. Select OK.

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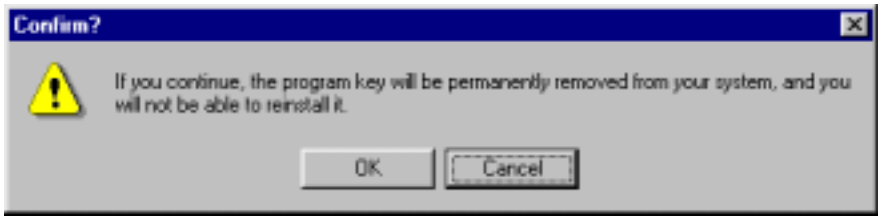
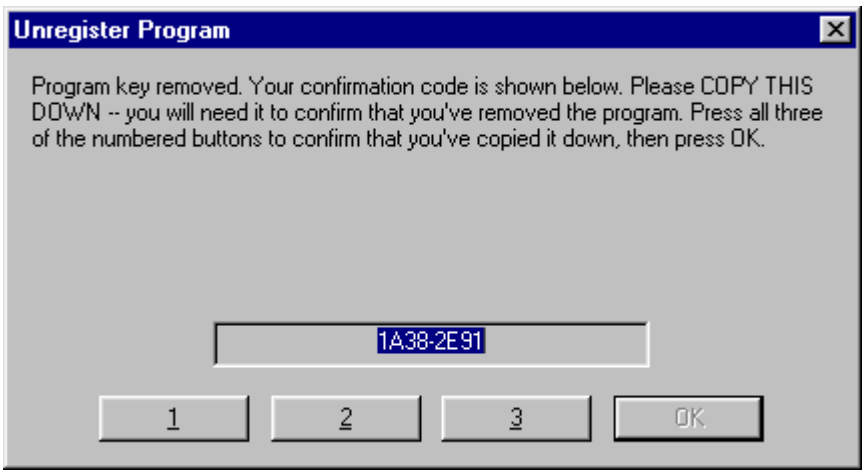

Confirm?
If you continue, the program key will be permanently removed from your system, and you will not be able to reinstall it.
OK
Cancel

To unregister it is necessary to provide a code which verifies that ROMDAS has been removed. An example of this code is shown on the screen below. **WRITE THIS CODE DOWN**. It is necessary to press all three buttons and then **OK** to complete the unregistering.


Unregister Program
Program key removed. Your confirmation code is shown below. Please COPY THIS DOWN -- you will need it to confirm that you've removed the program. Press all three of the numbered buttons to confirm that you've copied it down, then press OK.
1A38-2E91
1
2
3
OK

Send this code along with the new hardware fingerprint to DCL at the contacts above and a replacement key will be provided.

NOTE: If you need to install ROMDAS on another computer because of hardware failure during a survey and have no away of easily contacting DCL to obtain a new registration key remember that the software will install and run for 30 days on a computer that it hasn't been installed on before. This 30 days period should allow you to complete your work in progress.

2.7 Running ROMDAS for Windows

Menu Options

The opening menu for ROMDAS is shown below. It has the following options:

- **Survey**. Conduct any of the ROMDAS surveys;
- **Odometer System**. Use ROMDAS as a digital trip meter;
- **View Survey Data** View Exported raw or Processed MDB files;
- **Data Processing**. Analyse the survey data;
- **Setup**. Define setup options;
- **Information**. Information about the software.

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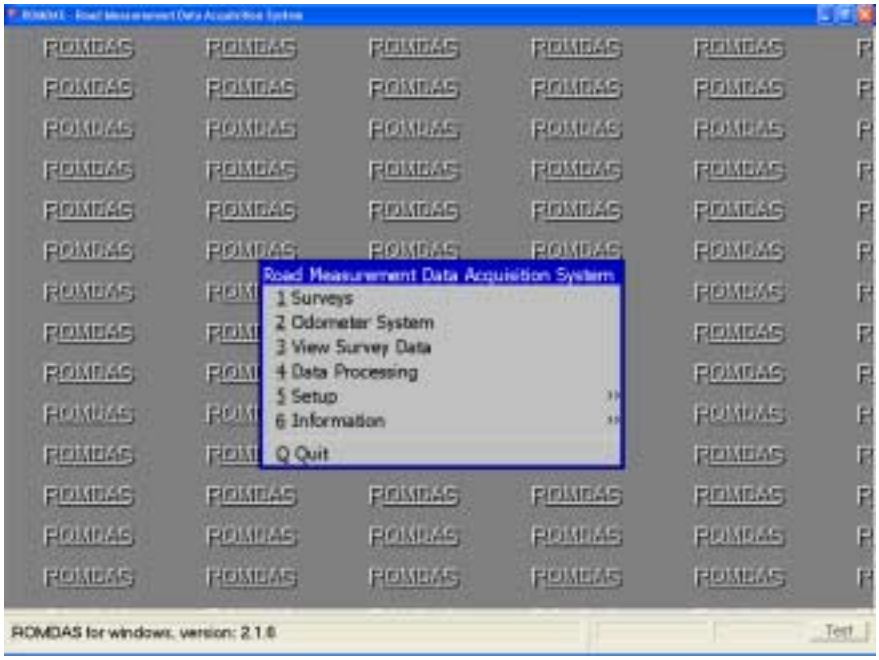

Navigation

Since ROMDAS is used in a moving vehicle, the system has been designed to be operated without needing a mouse. Navigation is done as much as possible with standard Windows navigation keys:

- **Up/Down Arrow Keys**. Highlight a menu item
- **Tab**. Move between fields
- **Enter**. Select a menu item
- **ESC**. Close the menu
- **Function Keys**. Assigned to specific tasks

Passwords

Many of the ROMDAS features are also protected by the registration system. This is because there are different charges to have access to different surveys. For example, the user can purchase a base system for roughness surveys only, and then upgrade to also log GPS data.

When a system is initially purchased users are given a **temporary password** until full payment for the system is received. Typically, this password lasts for 30 days. If your system does not work or you require an update to your password please contact info@romdas.com.

Also the **Setup|Options** menu can be password protected. This is because the settings here are critical and should only be altered by the System Administrator. If enabled selecting **Setup|Options** from the main menu gives the password entry box shown below:

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The first time using the software the password is not set therefore the user has direct access to the **Setup|Options** menus.
The password is defined as described in Section 16.3.

Test Mode

ROMDAS is normally operated with the ROMDAS hardware interface. However, the system can be run without the interface or being in the vehicle using the 'Test Mode' option. This simulates driving down the road. It is activated by the button labelled **Test Mode** at the bottom right of the screen (see below).

ROMDAS Tester

Hardware 'tester' is provided with ROMDAS. This instrument connects the to the interface BI and odometer ports and sends signals to the ROMDAS hardware interface in the same manner as if the interface was installed in the vehicle. This makes it possible to become familiar with the operation of ROMDAS in an office setting.

The photo to the right shows the tester connected to the hardware interface. The tester does not need external power to operate. Some older Testers also have a toggle switch to allow testing of the Hardware Interface reverse input. An optional 12V power supply (not provided) needs to be connected to these testers to do this.

The two dials on the tester are used to control the rate that pulses are sent to the interface. One dial controls the two BI input pulses; the second the odometer pulses. The toggle switch on the top switches between forward and reverse directions (if external 12V power is connected) .

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3 Installing and Testing the Survey Hardware

3.1 Introduction

Overview

There are a number of different components to install before surveys can be done. A basic ROMDAS system, comprised of the hardware interface and roughness meter, can typically be installed in about 2 hours. More complicated systems, such as the video, may take 3-4 hours. In general, less than a day is required to install a full ROMDAS system into a vehicle.

It is not necessary to have specialist tools or services to install ROMDAS, although access to a vehicle hoist or work pit is useful for installing the odometer sensor and bump integrator.

This chapter covers installing and testing the various ROMDAS instruments. It also includes setting up the system for using with digital cameras and voice recording.

Tools Required

The following tools are required:

- Multimeter (supplied with ROMDAS)
- Electrical Tape (supplied with ROMDAS)
- Sharp knife
- Pliers
- Screw Driver
- Spanners
- Electric Drill with 20 mm drill bit (for roughness meter)

3.2 Installing the Odometer Sensor

Types of Sensors

The installation requirements for the speed/distance sensor depend upon the type of sensor. Appendix A describes how the appropriate sensor should be selected. There are three types of standard speed/distance sensors available for use with ROMDAS:

- **Screw-in Transmission Speedometer Cable Sensor.** This connects at the junction between the speedometer cable and the transmission. It fits most modern Japanese vehicles and screws directly to the transmission. The speedometer cable is then connected to the sensor. It is fast and easy to fit but it does not fit all vehicles.
- **Splice-in Speedometer Cable Sensor.** This is spliced into the speedometer cable housing with the existing speedometer cable running through the centre of the sensor.
- **Electronic Speedometer Sensor.** This is used in vehicles that have

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electronic speedometers. It monitors the pulse line and returns a signal for each pulse. This works on most vehicles with the only problems reported with a Nissan utility.

The standard sensors are illustrated in the following photograph.

There are two special sensors:

- **Proximity sensors** are affixed to the inside of the wheel and monitor when the hub rotates. These are used when one of the first three sensors (or the high resolution DMI) is unsuitable.
- **High Resolution DMI.** This is a special sensor used when very high accuracies are required (see Appendix A).

Installation Instructions

Detailed instructions on installing the sensors are given in Appendix A.

3.3 Connecting the Power

Options

There are two options available for supplying power to ROMDAS:

- **Power Cable**. This is used when there is only a single hardware interface needs to be powered the cable can be directly connected to the vehicle cigarette lighter socket.
- **Power Distribution Box**. The distribution box is used when there are multiple instruments to connect (*i.e.* GPS, gyroscope, video system, *etc.*).

The power plug used for the ROMDAS instruments is through a two-pin screw in connector, shown in next diagram. The pin connections and

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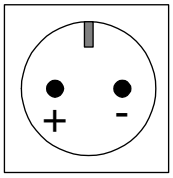
wiring are given below. The figure shows the connections when looking at the plug.

Positive (+)	Brown wire
Negative (-)	Blue or White wire



The installation requirements of both are different, and they are covered below.

Power Cable

The ROMDAS power cable[2] is illustrated below and the labelled components are as follows:

- **Power In**. The end of the cable with a cigarette lighter plug connected to it is used to power the ROMDAS unit. A 7 Amp fuse is contained in the cigarette lighter plug.
- **Interface Power**. This cable provides power to the ROMDAS hardware interface. It has a screw-in plug.

[2] The Power Cable replaces the ROMDAS Power Switch.

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Power Distribution Box

The ROMDAS power distribution box is shown below. It is used when there are multiple instruments that need to be run—typically a video system or a TPL and GPS. The power distribution box provides multiple power points for ROMDAS instruments, each individually fused.

The power distribution box has a battery cable. This should be run through the firewall of the vehicle to the engine compartment and the two circular connectors attached to the positive (RED wire) and negative (BLACK) wire terminals. Care should be taken to ensure that the wires are clear of all moving parts and high-tension leads.

The power distribution box should be positioned in the vehicle so that the On-Off switch is readily accessible and the instruments can be easily connected. Double-sided Velcro is supplied to help ensure that the power distribution box is held firmly in place.

3.4 Installing the Hardware Interface

Components

The following components are required for installing the hardware interface in the vehicle:

- ROMDAS hardware interface
- Cable ties
- ROMDAS power cable
- RS-232 cable
- Reverse light cable (optional)
- Adhesive Velcro

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Positioning the Interface

The interface should be positioned in such a way that:

- The lights on the interface are visible. This allows the operator to confirm that the data are being received.
- It is protected from collateral damage such as being stepped on;
- It is within reach of the cables.

ROMDAS is supplied with double sided Velcro tape, which is suitable for positioning the interface in many different ways and to hold it, steady. The photo to the right is an example of an installation at the rear of the centre console in a Pajero that was done using the adhesive Velcro.

Connecting the Cables

- **Odometer Cable**. The cable connecting the odometer sensor needs to be run into the vehicle. This is done either via an existing hole in the firewall or by drilling a new hole.
- **Roughness Cable**. The BI extension cable should be run to the bump integrator if roughness is to be measured.
- **Power Cable**. **ENSURE THE POWER IS TURNED OFF BEFORE CONNECTING**.
- **RS-232 Cable.** The RS-232 cable should be screwed into the interface and then run to the computer.

The cables are usually wrapped together with tape or cable ties. For protection they should then be run under the carpets, seats, consoles to the point where the interface will be mounted before connecting them to the interface. The top of the interface is labelled with the location of the different connections.

Reverse Light Cable

A cable is supplied which can be connected to the reverse light. This is only required if the vehicle will be operated in a reverse direction. This will tell the system to decrement the chainage instead of increasing it.

3.5 Installing the Transverse Profile Logger

Instructions

The transverse profile logger (TPL) must be mechanically mounted in the front of the vehicle. It is connected to the computer via a serial port. Detailed instructions on installing the TPL are given in Appendix D.

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Components

The following components are required for installing the TPL:

- TPL Master Controller
- TPL 3m housing with electronics
- Cables

3.6 Installing the Video System

Instructions

Detailed instructions on installing the video system are given in Appendix E.

Components

To record video images data the following components are supplied:

- Video camera
- Firewire PCMCIA Card if computer does not have a Firewire port
- Cables
- Power supply

The components depending upon the type of video system purchased. The components provided with each system are described in Appendix E.

Positioning the Camera

The camera should be positioned on the vehicle so that it has a clear view of the road right-of-way. If the vehicle will be operated in rainy conditions it is advisable to mount the camera inside the vehicle otherwise it will be necessary to regularly stop and wipe clean the lens on the camera housing.

3.7 Installing GPS Receivers

Instructions

Detailed instructions on installing GPS receivers are given in Appendix F.

Components

To record GPS data the following components are supplied:

- GPS receiver
- Cable to supply power to receiver
- GPS antenna
- RS-232 cable to connect GPS receiver to computer

There may be additional components depending upon the type of receiver used. The components provided with each receiver are described in

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Appendix F.

Positioning the GPS Unit

The GPS receiver should be positioned so that it is clear of the floor. With the Trimble Pocket Pathfinder the unit can be affixed to the vehicle body using double-sided Velcro. With the Garmin 12XL an optional kit is available to hold the unit or it can also be mounted with adhesive Velcro.

The antenna is usually mounted on the roof of the vehicle or, with the Garmin 12XL, on the inside of the windscreen using the suction cup kit. The antenna should have as clear a view of the sky as is practicable.

Activating GPS Measurements

Activating GPS measurements are described in Chapter 11.

3.8 Installing the Gyroscope

Instructions

Detailed instructions on installing the gyroscope are given in Appendix F.

Components

The gyroscope data are used to estimate the GPS co-ordinates of the vehicle when there is a loss of satellite lock. The gyroscope outputs the heading change (in degrees) and this is used with a Kalman filtering approach to establish the position.

The following components are supplied with the gyroscope:

- Gyroscope
- Gyroscope cable
- Mounting plate
- 4 x self-tapping screws for mounting plate to vehicle
- 4 x screws and washers for gyroscope to mounting plate

Positioning the Gyroscope

The following should be considered when positioning the gyroscope:

- It must be mounted at least 300 mm away from any magnetic source—the further the better
- It must be mounted as parallel as possible to the normal horizontal axis of the vehicle
- It must not be exposed to direct sunlight
- It must be kept dry

It is recommended that it be mounted in either the boot (trunk) of the vehicle or under a seat.

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The gyroscope's internal circuitry generates a nominal amount of heat that must be conducted away to maintain an operating temperature within specified levels. The base plate of the gyro should be in full contact with a metal surface of at least 0.043 m^2. The supplied mounting plate meets this criteria.

Installing the Gyroscope

Once a suitable position has been established the following is done:

- Attach the gyroscope to the mounting plate
- Connect the gyroscope cable
- Position the mounting plate as described above
- Ensure that the arrow adjacent to the cable connection is pointing to the front of the vehicle. It **must** be within 5 degrees of the direction of travel
- Mark the position of the four corner holes in the mounting plate
- Remove the mounting plate and gyroscope
- Drill holes in the vehicle corresponding to the corner holes
- Install the mounting plate and gyroscope
- Run the gyroscope cable to the data collection computer

3.9 Installing the Laser Profiler

Instructions

Detailed instructions on installing the Laser Profiler are given in Appendix C.

Components

The Laser Profiler data gives the longitudinal profile of the pavement for determining roughness in IRI (mm/km).
The following components are supplied with the Laser Profilometer:

- Laser Unit
- Ethernet Switch
- High Resolution DMI
- Laser DMI Interface
- Mounting Bar
- Cabling

Positioning the Laser

The following should be considered when positioning the Laser:

- It must be mounted at least 430 mm away from the road surface when the vehicle is carrying its expected weight
- It must be mounted as parallel as possible to the road surface
- It must be kept dry

Installing the Laser

Once a suitable position has been established the following is done:

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- Attach the laser to the mounting bar
- Mount the High Resolution DMI to the wheel
- Connect cabling
- Software setup

3.10 Digital Cameras

Overview

Digital cameras can be used during ROMDAS surveys for taking still photographs of roadside events, such as location reference points, structures, *etc.* By linking the digital photographs to keyboard events, ROMDAS will store the file name when the photograph is taken. The photographs can then be readily accessed from database management systems.

Activating Digital Camera Photos

The settings for the digital photographs are located under:

Setup|Options|Digital Camera Settings

Selecting this gives the screen to the right. Where the user defines the digital photograph settings

- **Generate File Name**: This will see the name of the photograph generated and stored with the data files.
- **Camera Type**: The type of camera used. Each camera has its own unique naming convention which numbers the digital photographs sequentially, the following are the conventions used with each camera, where xxxxx is a sequential number.

Fuji MX 1200	DSCfxxxx.jpg
HP C20/C30	DSCxxxxx.jpg
Ricoh 6000	RIMGxxxx.jpg
Sony DSC-F505	DSCxxxxx.jpg

- **Defined Camera File Name:** Additional cameras can be included by selecting **NEW** as the camera type and defining the camera name in the window to the top right. The character prefix and the number of characters are then defined based on the naming convention used by the camera (bottom right).

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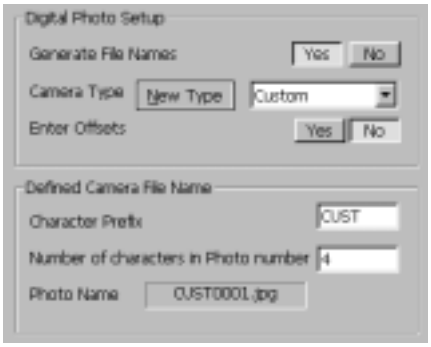


Using Digital Cameras in Surveys

Having activated the digital camera option it is necessary to associate a keyboard event with a digital photo (see Section 6.3). A detailed description of taking digital photos in surveys is given in Section 7.4.

3.11 Voice Recordings

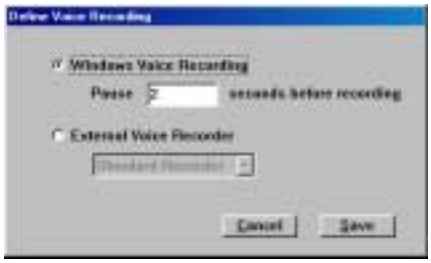
Overview

Voice recordings can be made during surveys and associated with specific events, for example a description of a roadside feature. ROMDAS is designed to use either the survey computer's ability to record voice files (internal recording) or an external recorder.

Both of these are activated by associating a keyboard event with a voice recording event (see Section 6.3). When the key is pressed a file name will be stored with the event containing the name of the voice recording. This facilitates play back after the survey. If internal recording is used there is no post-processing required; with external recording some naming of the files is necessary, as well as digitising of the voice file if a tape recorder was used.

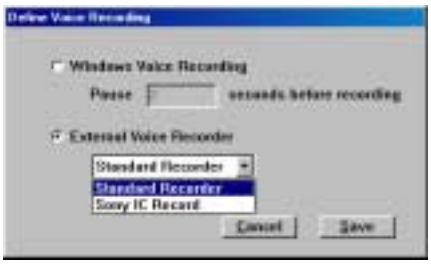
Internal Recording

The window to the right shows the settings for the internal recording. It is accessed using the **Define** button when associating a voice recording to the keyboard event. The user can define the length of pause before recording starts.



External Recording

The external recording is designed to be used with a standard tape recorder or a Sony IC recorder. The latter directly digitises the files and the file names are stored in the appropriate format with the event data.



Using Voice Recordings in Surveys

Having activated the voice recording option it is necessary to associate a keyboard event with a voice recording (see Section 6.3). A detailed description of using voice recordings in surveys is given in Section 7.5.

3.12 Installing Additional Communication Ports

Overview

Most computers, particularly notebooks, come with a single COM port. This is usually used for the ROMDAS hardware interface. When using additional instruments it is necessary to add extra COM ports, either via a PCMCIA serial card or through a USB to RS-232 hub.

All devices require drivers to run under Windows. These should be supplied with the system otherwise they can be located on the ROMDAS CD under the **Software|Drivers** folder (see below).

When new hardware is being installed the Windows ‘Add New Hardware’ wizard runs. Always have Windows search for a new driver and ensure that the appropriate location is selected (see below).

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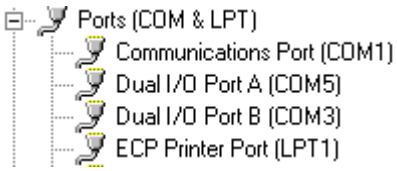
Once a device is installed, it should be verified from the **Windows Control Panel**.

- Select **Start|Settings|Control Panel**
- Select **System | Device Manager** and the window to the right is opened. This lists the devices installed on the computer.
- Expand the entry for **Ports (COM & LPT)**

The available ports will be listed, such as shown below which gives the ports with a Socket IO dual PCMCIA card.



Socket IO PCMCIA Serial Cards

- Insert the Socket IO card in the PCMCIA slot. The Windows 'Add New Hardware' wizard starts
- Insert the floppy disk with the driver in the computer's floppy drive. If this is not available the driver is on the ROMDAS CD in the folder software\drivers\Socket IO. There are different folders depending on whether or not the card is a single, dual, or quad serial card. If the driver is found the screen to the right will be displayed.

- Select **Next**. The driver will be installed. If successful, the screen to the right will be displayed.
- Select **Finish** to complete the installation.

Once installed the status of the card can be investigated under the **Windows Control Panel** through the Socket IO icon.

Selecting this will give the display (below left) that lists the COM ports available to the card (here COM3 and COM5). It is important to note the port COM setting and match this to the port on the card as well as to the correct instrument that is to be connected to the port. The 'Advanced' tab shows the I/O address and interrupt assigned to the card.

Eiger-Fujitsu PCMCIA Serial Cards

- Insert the Eiger-Fujitsu card in the PCMCIA slot. The Windows 'Add New Hardware' wizard starts
- Insert the floppy disk with the driver in the computer's floppy drive. If this is not available the driver is on the ROMDAS CD in the folder 'Fujitsu-Eiger'. If the driver is found the screen to the right will be displayed.
- Select **Next**. The driver will be installed. If successful, the screen to the right will be displayed.
- Select **Finish** to complete the installation.

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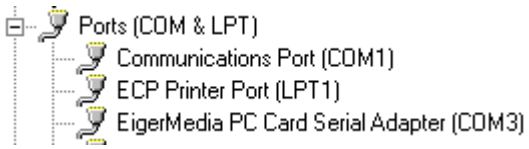
After installation the settings can be viewed under the system as shown below. Here, the PCMCIA card has been loaded as COM3.



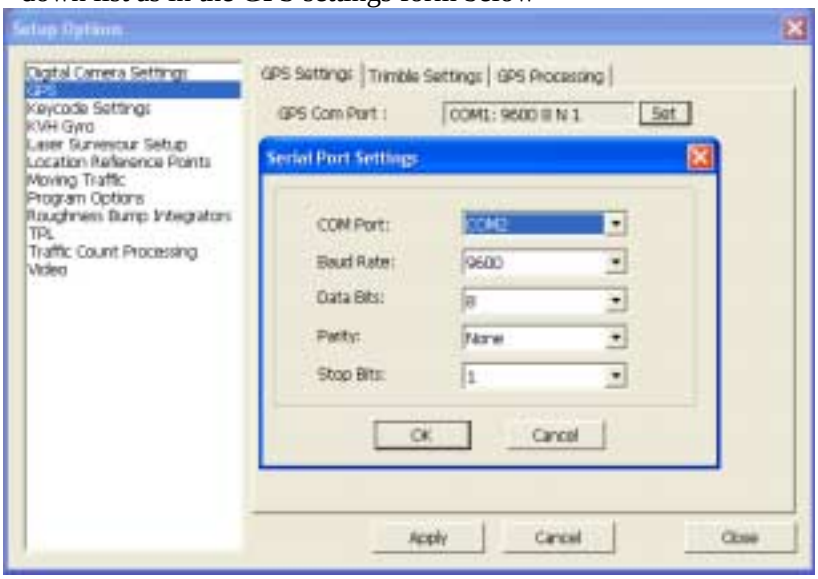
3.13 Setting Communication Parameters

Assigning COM Ports

It is necessary to assign the communication (COMM) ports that each instrument will operate at. These are defined through the **Setup Options** dialog form for each device:

The following should be noted:

- Each instrument **must** be assigned to a different COM port. The drop down list will list the available COM ports and any existing ROMDAS Instrument COM port assignments
- Some instruments need to have Baud rate and other serial parameters set to match the settings on the instrument. Where this is applicable an additional **Set** button will be available beside the COM port drop down list as in the GPS settings form below



The table below lists the appropriate values for the different instruments used with ROMDAS.

Instrument	Supplier	Settings

These settings cannot be changed for the following instruments: -

Hardware interface	DCL	38400,N, 8,1
Transverse Profile Logger	DCL	19200,N, 8,1
Skid Resistance	Findlay Irvine	9600,N, 8,2

These settings must match the settings on the Instrument but usually are set to: -

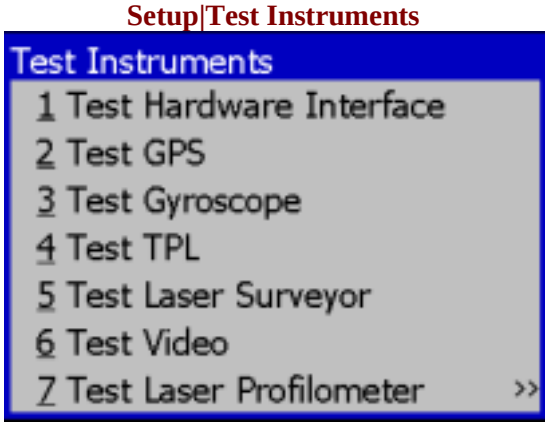
GPS – Garmin 12XL	Garmin	9600,N, 8,1
GPS – Trimble Pocket PF	Trimble	9600,N, 8,1
GPS – Trimble Pro-XRS	Trimble	9600,N, 8,1
Gyroscope	KVH Auto Gyro	4800,N, 8,1
Gyroscope	KVH E Core 2000	9600,N, 8,1
Laser Surveyor	Laser Atlanta	4800,N, 8,1

3.14 Testing the Instruments

Overview

The final step of the installation process is to test the instruments using the test menu below which is located at:

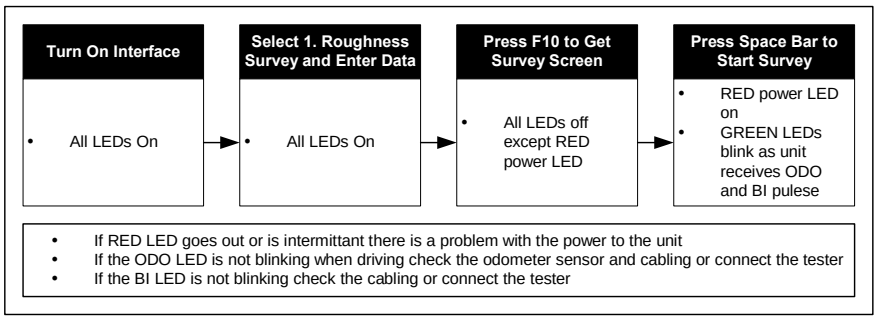
Setup|Test Instruments



Test Hardware Interface

The ROMDAS hardware interface has a series of LEDs on the unit to assist with testing and diagnostics. The chart below summarises how these are used to investigate problems with the interface or the connections when executing a roughness survey, either in a vehicle or with the ROMDAS tester.

V5.3 and earlier


Turn On Interface
• All LEDs On
Select 1. Roughness Survey and Enter Data
• All LEDs On
Press F10 to Get Survey Screen
• All LEDs off except RED power LED
Press Space Bar to Start Survey
• RED power LED on
• GREEN LEDs blink as unit receives ODO and BI pulese
• If RED LED goes out or is intermittant there is a problem with the power to the unit
• If the ODO LED is not blinking when driving check the odometer sensor and cabling or connect the tester
• If the BI LED is not blinking check the cabling or connect the tester

V5.4

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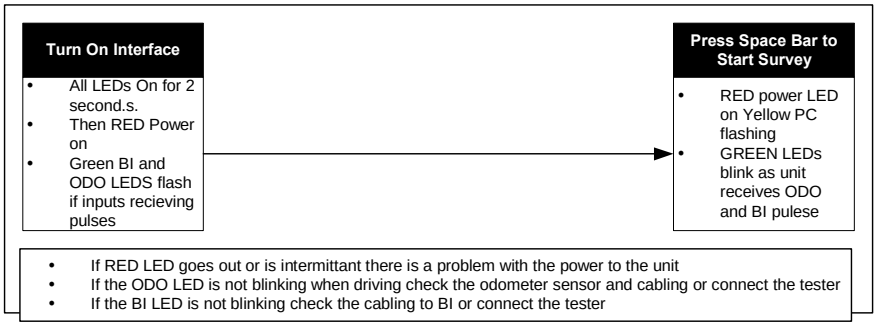
Turn On Interface
• All LEDs On for 2 second.s.
• Then RED Power on
• Green BI and ODO LEDS flash if inputs recieving pulses
Press Space Bar to Start Survey
• RED power LED on Yellow PC flashing
• GREEN LEDs blink as unit receives ODO and BI pulese
• If RED LED goes out or is intermittant there is a problem with the power to the unit
• If the ODO LED is not blinking when driving check the odometer sensor and cabling or connect the tester
• If the BI LED is not blinking check the cabling to BI or connect the tester

Test GPS

The 'Test GPS' option is used to test the receiver to ensure that data are being received. A successful test shows:

- The instrument is connected to the appropriate port; and,
- The correct instrument settings are in the ROMDAS software. As described in Chapter 11, there are several different ways of data being transmitted from the GPS receiver to ROMDAS and it is important that the system be properly set.
- Select the type of GPS to use
  - Trimble instruments should use Trimble TSIP protocol settings if available.
  - Other instruments NMEA
- Select **Setup|Test Instruments|Test GPS**
- Select **Start**

The data from the GPS receiver will be logged to the PC. It will be converted to the latitude, longitude and altitude. The screen below is an example of such data.

NOTE: It is common for receivers to take several minutes to initialise and begin logging their data so do not be worried if there is a delay is displaying the location.

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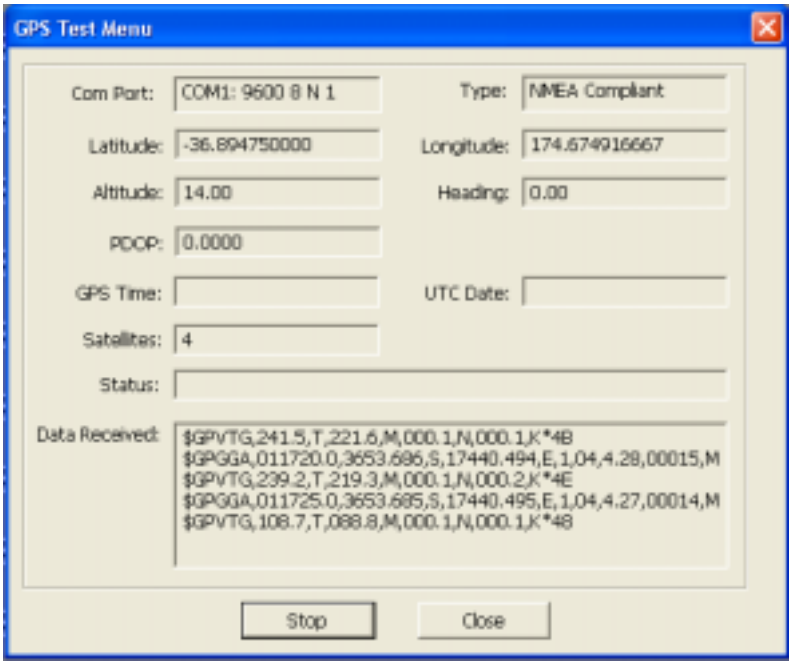

The following should be noted with regard to this test:

- If the GPS time is displayed but there is no position information (latitude, longitude, altitude) this is because there are insufficient satellites in view. Try moving the antenna
- If there is no GPS time:
  - Ensure that the antenna can see satellites (*i.e.* is it outdoors in an open area?)
  - Check the communications parameters and COM Port through the Test COM Port menu

Test TPL

The 'Test TPL' option is used to test the Transverse Profile Logger instrument. This instrument is used to obtain the transverse profile of the road to measure rut depth.

- Connect the TPL Master Controller
- Select **Setup|Test Instruments|Test TPL**

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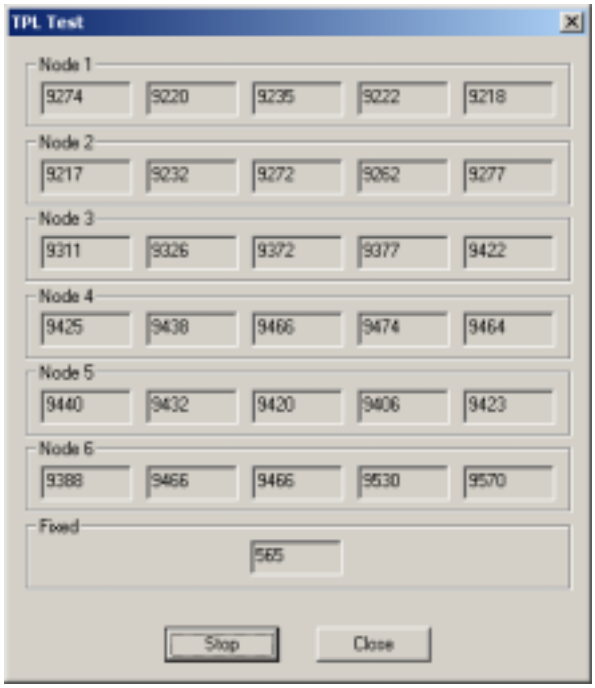
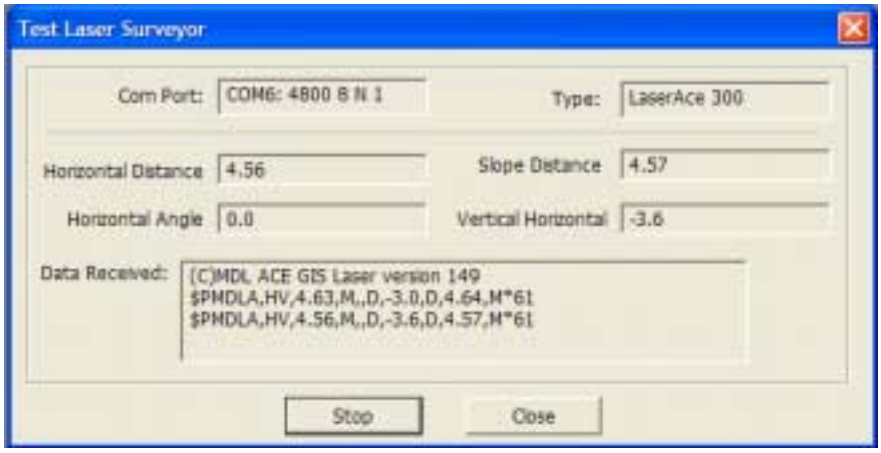


Test Laser Surveyor

The 'Test Laser Surveyor' option is used to test the hand-held Laser Surveyor instrument. This instrument is used to obtain the position of objects adjacent to the road.

- Select **Setup|Test Instruments|Test Laser Surveyor**
- Point the laser at an object at least 5 m away
- Press the trigger



The screen should display the distance to the object, its bearing and the slope.

If there is no data received check the communications parameters and COM Port through the Test COM Port menu.

Test GripTester

The 'Test GripTester' option is used to display data received from the

GripTester skid device. When selected, a plot will be displayed of the GripTester data received.

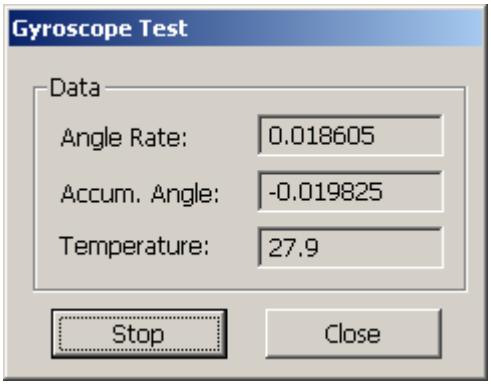
If there is no data received check the communications parameters and COM Port through the Test COM Port menu.

Test Gyroscope

The 'Test Gyroscope' option is used to test the ROMDAS GPS gyroscope that is used for heading corrections when there is loss of satellite lock.

- Place the gyroscope on a level surface
- Connect the power to the gyroscope and the gyroscope to the data logging computer
- Start the gyro test.

The display will be as shown below. With the gyroscope motionless, the Angle Rate should be < 0.2 degrees/second. If not, run a bias correction test as described in Section 5.6.



Test Laser Profilometer

The 'Test Laser Profilometer' option is used to test the ROMDAS Laser IP connections.

- Connect all cables
- Connect the power to the Laser
- Start the laser Connections test

The display will be as shown below showing the IP connections of each unit.

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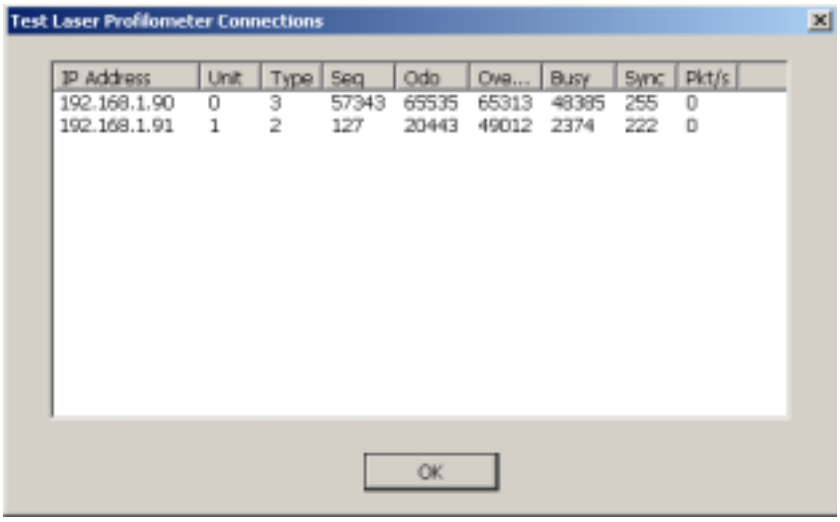

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4 Principles of Road Measurement

4.1 Introduction

Overview

Before describing the ROMDAS and its features, it is important to appreciate some of the principles of road measurement. A proper understanding of these principles will ensure that the ROMDAS system is used to its full potential.

Terminology

The following terminology is employed in this User's Guide:

- **Chainage:** the location along a road from a start point (in m).
- **LRP:** Location Reference Point. A permanent marker or feature adjacent to the road used as a reference point for surveys.
- **Keyboard rating:** recording events with the PC (or external rating) keyboard.
- **Continuous event:** an event on, or adjacent to, the road which applies over a section of the road (e.g. a cracked section)
- **Point event:** an event on or adjacent to the road which applies to a point (e.g. a traffic sign or culvert).
- **Sampling interval:** the interval over which data are recorded. It is usually 100 - 1000 m for roughness surveys.
- **Transverse profile:** the pavement profile across a lane.
- **Longitudinal profile:** the pavement profile along a lane.

4.2 Location Reference Points

Using LRPs

When conducting a survey, be it of road roughness, pavement condition, or roadside events, the most important single consideration is the location referencing system. The location referencing system used with ROMDAS is a linear system, that is, the survey starts at a given point and progresses along the road. Thus, the survey chainage increases when driving away from the start point and decreases when heading back along the same road towards the start point.

Surveys are always done between a start and end point. The common practice is often to only record these two chainages, however, this is inadvisable. No matter how well calibrated a distance/speed sensor is, there will be variations in the lengths recorded between different surveys on the same road. This will create problems in reconciling data.

A better approach is to have regular **Location Reference Points (LRPs)** along the road. These can be existing km stones, culverts, buildings, signs, or any physical feature which will not change between surveys. By selecting LRPs at regular intervals, generally 1 km, one minimises the

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errors between different surveys, particularly those conducted in successive years. This is done by resetting the chainage at each LRP thereby expressing all data in terms of the offset from the last LRP.

To illustrate the importance of using LRPs and resetting the chainages at each LRP, consider Figure 4.1. This consists of a road which has been accurately surveyed and has LRPs at 1000 m and 2000 m.

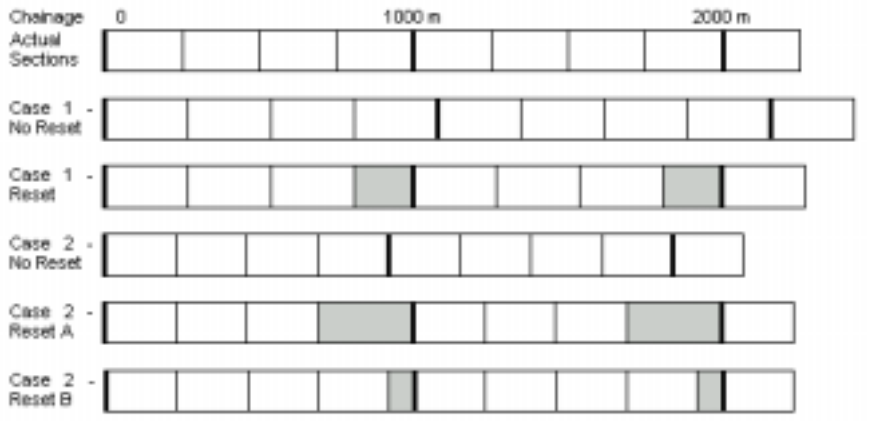

Figure 4.1: Implications of LRP Resets on Survey Chainages

No matter how well calibrated the odometer is, it will never read exactly the same in two surveys of the same road. This applies not only to the ROMDAS, but to any distance measuring device. Proper calibration limits these effects, but they can never be eliminated. Thus, in each subsequent survey the sections will not be identical, with the chainage errors accumulating as one travels along the road.

In Case 1, the odometer is underestimating the distance. As a consequence, the actual sampling intervals are greater than the target 250 m. At the first LRP there is only a small difference, however, as one continues along the road the errors accumulate so one eventually has the target segments completely out of synchronisation with the actual segments.

However, were one using LRP resets the errors would not accumulate and would only pertain to the last sampling interval. This is illustrated in Figure 4.1 under “Case 1 - Reset” where the final sampling interval before the LRP reset is shorter than the others. At each LRP the data are resynchronised thereby ensuring that the errors are confined to each section. It is also important to note that the data, for example the roughness, is calculated on the actual distance measured so the value will be representative of that actual segment, even though they are measured on a shorter segment.

Case 2 arises when the odometer is over-estimating the chainage. As in Case 1, the error accumulates so the sections are soon unsynchronised. In this instance, ROMDAS synchronises the sections depending upon the distance after the last sampling interval when the LRP is recorded. Two situations arise:

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- the user can specify a distance after the LRP to increment to the next LRP. By default, this is set at 100 per cent of the sampling interval. If the LRP is recorded within this zone, the data will be stored as in "Case 2 - Reset A";
- if the LRP is not recorded within this zone, the data are recorded as "Case 2 - Reset B".

Implications of Odometer Error

To illustrate the importance of resetting chainages at LRPs, consider the following example from a typical (and real life) odometer calibration. Three runs were made with the vehicle over a 200 m section. The number of odometer pulses recorded were 973, 975 and 977 over the section. These corresponded to 4865, 4875 and 4885 pulses per km. Assuming that the mean of 4875 is appropriate, the following is the distances that would have arisen with each of these values:

Distance in km	Distance that Would Have Been Recorded in Surveys by Calibration Factor		
	4865	4875	4885
1.00	1.00	1.00	1.00
2.00	2.00	2.00	2.00
3.00	3.01	3.00	2.99
4.00	4.01	4.00	3.99
5.00	5.01	5.00	4.99
10.00	10.02	10.00	9.98
15.00	15.03	15.00	14.97
20.00	20.04	20.00	19.96
25.00	25.05	25.00	24.95
30.00	30.06	30.00	29.94
35.00	35.07	35.00	34.93
40.00	40.08	40.00	39.92
45.00	45.09	45.00	44.91
50.00	50.10	50.00	49.90

The above data show that the small difference of 2 pulses over 200 m can translate into an error of 100 m over 50 km. Over short distances, such as are used with LRP resets, the error is small enough to be ignored.

Importance of LRP Resets

The importance of using LRP resets cannot be overemphasised. Highway agencies which do not use these invariably have problems reconciling their data from year to year. Many have to resort to sophisticated (or not so sophisticated!) processing algorithms ("rubber banding"), while others simply give up in frustration. ROMDAS has been designed in such a way that you can easily avoid these problems. Because of that we **STRONGLY** recommend the use of LRP resets.

ROMDAS has been designed to make full use of LRPs. The software will

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let the user supply a file containing a list of LRPs and their chainages, as recorded in a previous survey. As the survey progresses, the ROMDAS informs the operator that the vehicle is approaching an LRP established in a previous survey along with a description of the LRP. The operator will then press the ESC key when the vehicle is adjacent to the LRP. The recording is then reset thereby ensuring that the data corresponds exactly to the measurements made in previous surveys. The end chainages can be synchronised by replacing the surveyed chainage with the measured chainage from the LRP survey. It is also possible to insert new LRPs into an existing file or even to create an entirely new LRP file during a survey.

It is recommended that the chainages of the LRPs be established either in a separate survey or during the first roughness survey. These LRPs can then be used in all future surveys to ensure sampling consistency.

4.3 Distance Measurement Accuracy

Measurements

The above discussion of LRPs touched upon the issue of measurement accuracy. It must be appreciated that the accuracy of your distance measurement is directly proportional to the number of pulses measured per km. Typically, vehicles generate 2000 - 5000 pulses/km. This corresponds to 0.5 - 0.2 m/pulse which is adequate for most applications.

The exception to this is when looking at acceleration behaviour in travel time surveys. Unless there is approximately 5000 pulses/km one finds that the results are insufficiently accurate to get a good estimate of the acceleration behaviour. The ROMDAS High Resolution Distance Measurement Instrument (HRDMI) is available for situations where high resolutions are required.

4.4 Visual Keyboard Rating

Principles

The principle behind keyboard rating is to use the survey vehicle to establish the chainage of features, pavement condition or other roadside events.

Types of Events

Before undertaking keyboard rating it is necessary to break down the items to be measured into point and continuous events:

- a **point event** is something which exists at a single point in space, such as traffic signs or LRPs; or,
- a **continuous event** is something which exists over a section, such as pavement condition. Continuous events have two chainages: a beginning and end chainage.

There is a special type of continuous event called a **switch** event. This can be understood as a series of continuous events. For example, one may

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define a ranking for pavement condition from 0 to 5. These are continuous events so one would normally have to press two keys when changing; one to end the previous condition and one to apply to the new condition. Switch events remove the need to press two keys. When the second key is pressed the first event is cancelled[3].

Assigning Events

It is necessary to allocate an individual key on the computer keyboard to each event. These should be carefully selected so as to be both easily accessible and easy to remember. It is good practice to tape small labels to the keys identifying the event.

When recording pavement condition it is recommended that the severity of the event also be recorded. This is done by allocating several keys to the same event, each with differing severities, for example:

Key	Description
A	No cracks
S	Low cracking
D	High Cracking
F	Extreme Cracking

It is strongly advised that any severity rating system must include a ‘no defect’ condition since many models which use condition data have different functions for ‘no’ versus ‘some’ distresses.

When selecting the number of distresses to record, and their severities, always bear in mind the practical limitations of the operator. The greater the number to record the more difficult it is to get reliable and repeatable results.

Rating Keyboards

There are special 20 or 58 ROMDAS rating keyboards available which are designed to facilitate condition rating surveys. Each key can be individually programmed to any key on the computer keyboard. These greatly simplify the visual rating process. The programming of these keyboards is described in Appendix G.

20 Key Keyboard

58 Key Keyboard

For example, one can assign different distresses to the rows and different severities to the columns. This greatly simplifies the correct identification of the key to press for a distress. For inventory surveys the keys could be

[3] Normally, one has events that apply continuously along a section of road. For example, there will always be either no cracking or a level of cracking. ROMDAS defaults to having the user switch only between switch events; you cannot have ‘no’ event. However, this can be overruled in the keycode event setup screen.

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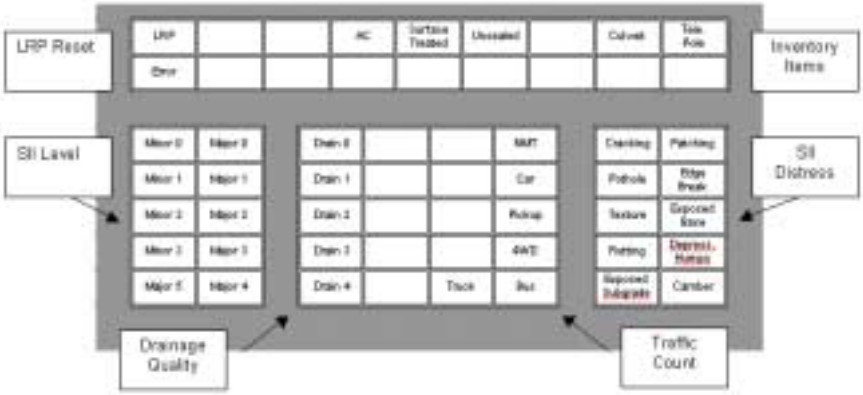
labelled with different inventory items. The figure is an example of how a 58 key rating keyboard could be labelled to collect different data. Here, the condition is being expressed in terms of the Surface Integrity Index which is a 0 to 5 scale[4].



It is possible to define keyboard events **before** the survey actually starts. This allows the operators to define the events so that they are initialised as soon as the survey begins. For further information on **Preliminary Keycodes** see Section 7.3

4.5 Surveying Adjacent Sections

The Problem

A problem can often arise when measuring two adjacent lanes on a two-lane road.

When the survey of the first lane is completed the vehicle must be turned around to measure the second lane. Roughness is measured over regular sampling intervals but the last interval is usually of a shorter length than the sampling interval. When measuring the roughness in the second lane unless the first interval length is the same as the last interval for the previous lane, the survey results will be staggered and not correspond to exactly adjacent sections. This problem can be visualised as under diagram (a).

ROMDAS allows the user to terminate a survey, reposition the vehicle and start the survey on the other lane. It adjusts the first interval length so that it is the same as the last interval for the previous lane. This ensures that the results of a roughness survey apply to adjacent samples. This is illustrated below under diagram (b).

[4] Paterson, W.D.O. (1993). *A Standard Surface integrity Index of Pavement Condition: Definition and Measurement Procedure*. Internal Paper, The World Bank, Washington, D.C.

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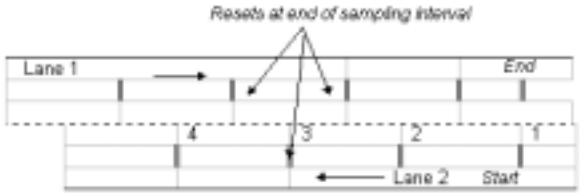
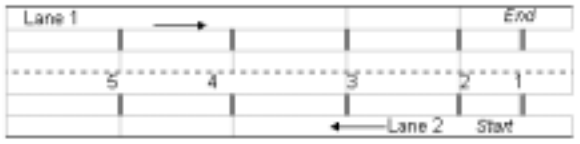


(a) Example of Adjacent Lanes With Shortened Interval at End of First Lane



(b) ROMDAS Approach

The user does not need to survey the other side of the road immediately. By opening an existing file the operator will be prompted if they want to continue an existing survey or survey the other side. This makes it possible to plan the surveys in the most efficient manner possible.

NOTE: This option cannot be used in conjunction with LRP resets. In such a case there should be separate files of LRPs for each lane. It will also not work if you are manually defining the end of the roughness sampling interval.

4.6 Programming a Survey

Overview

To improve the efficiency of the survey programme it is often necessary to interrupt what should be a continuous run to measure roads running off from the primary survey route. An example of this is shown below. The procedure to follow is:

- The operators shall terminate the main survey at an LRP or other roadside feature which will be easy to return to (Run 1). It is generally recommended that this be past the point where the other surveys are to commence.
- They may then execute the other surveys (Run 2 and Run 3).
- They shall return to where they ended the previous survey they enter the same Survey_ID as was used previously. They will then be given the option to **Continue the previous run**. The data collection will be started where they left off and, once processed, both components of Run 1 will be integrated.

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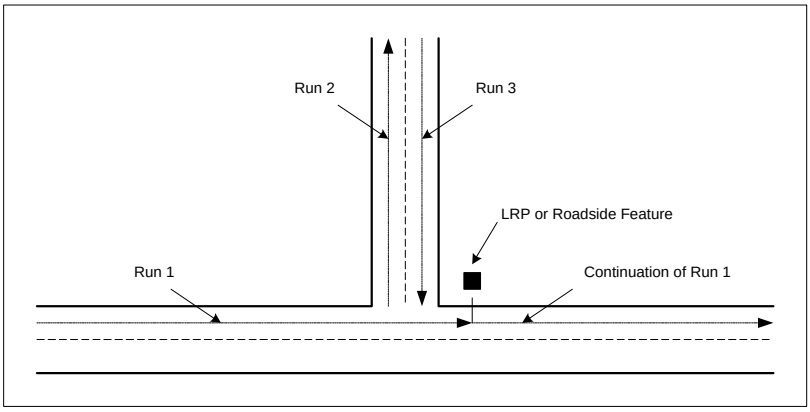
Run 2
Run 3
LRP or Roadside Feature
Run 1
Continuation of Run 1

5 Calibrating the Instruments

5.1 Introduction

Overview

Before any surveys can be conducted it is necessary to calibrate the instruments. The following calibrations must be done:

- **Odometer:** This is required for all vehicles. This ensures that the distances and speeds recorded by the survey vehicle are correct.
- **Roughness Meter:** The roughness meter must be calibrated against the International Roughness Index (IRI).
- **Transverse Profile Logger:** The distance measurements of the TPL must be calibrated and the instrument levelled.
- **Laser Profilometer:** The accuracy of the Profiler must be monitored with the Elevation and Bounce checks. If these tests don't meet the requirements or the Profiler or it is past its calibration expiry date the Profilometer should be returned for calibration.

5.2 Odometer Calibration

Frequency

Every 5000 km

Equipment Required

The following equipment are required:

- DMI and Roughness Calibration log **E012 Form 1** (see Appendix H)
- ROMDAS vehicle with DMI operating and computer installed
- Chalk for marking tyre
- Tyre pressure gauge
- Tape measure
- Paint for marking start and end of section.

Locating and Marking the Calibration Section

It is necessary to locate a section of road which is flat, straight with little traffic for the calibration and which is at least 100 m long (preferably 300 m or more).

- Locate the start of the section at a permanent feature, such as a traffic sign.
- Mark this start location with paint.
- Measure along the road with the tape measure to a second permanent feature.
- Mark this end location with paint.

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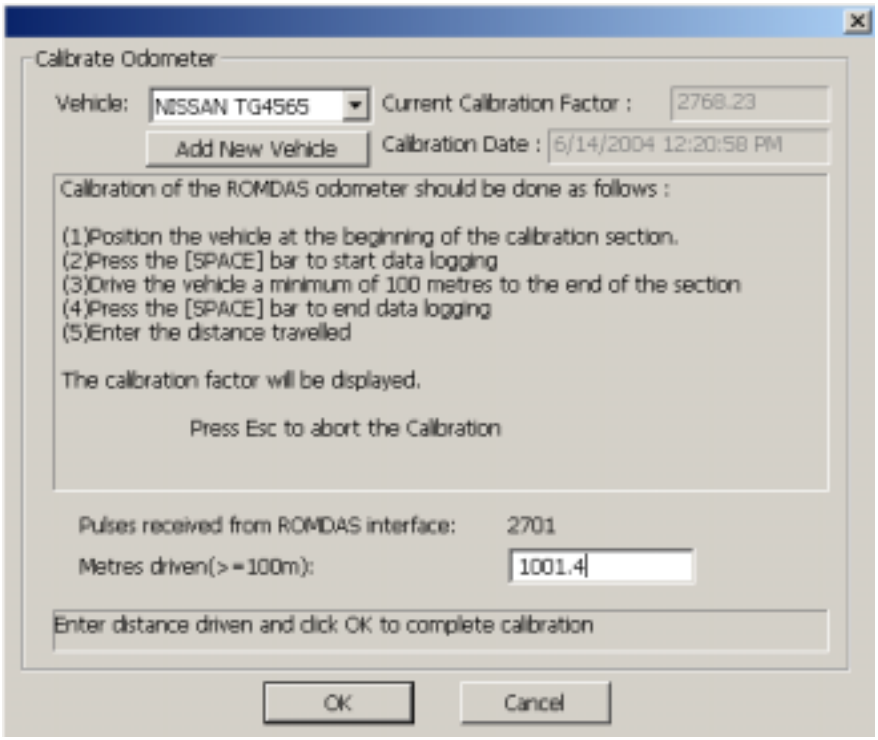
Calibration

Preparing the Vehicle

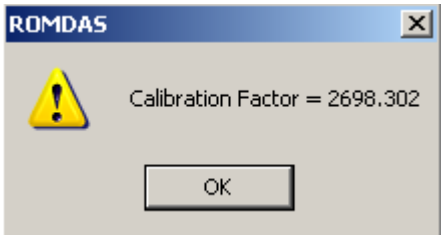
- Drive vehicle for minimum of 10 km to ensure that tyres are at operating temperature
- Check pressure with a tyre gauge and ensure that tyres are at their manufacturers recommended operating pressure.
- Park vehicle with **wheel** over the paint
- Mark tyre with white chalk where tyre meets paint

Running the Calibration

- Start the ROMDAS software
- Select **Setup|Calibrate|Calibrate Odometer|Run Calibration Test**
- Use the **Add New Vehicle** button to enter the name of the vehicle to be calibrated or select an existing vehicle from the drop down **Vehicle** list (see below).
- Press the **Space Bar** to start calibration
- Drive to end of the test section
- Stop vehicle so that the marked tyre is just past the paint mark on the road with the chalk mark vertical above the pavement
- Press **Space Bar** to end calibration
- Measure the distance from the centre of the paint mark to the chalk
- Enter the distance of the test section plus the distance from the paint to the chalk


Calibrate Odometer
Vehicle:
NISSAN TG4565
Current Calibration Factor :
2768.23
Add New Vehicle
Calibration Date :
6/14/2004 12:20:58 PM
Calibration of the ROMDAS odometer should be done as follows :
(1)Position the vehicle at the beginning of the calibration section.
(2)Press the [SPACE] bar to start data logging
(3)Drive the vehicle a minimum of 100 metres to the end of the section
(4)Press the [SPACE] bar to end data logging
(5)Enter the distance travelled
The calibration factor will be displayed.
Press Esc to abort the Calibration
Pulses received from ROMDAS interface:
2701
Metres driven(>=100m):
1001.4
Enter distance driven and click OK to complete calibration
OK
Cancel

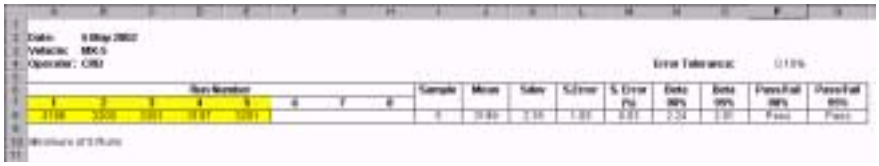
- Press **Enter** and the calibration factor will be displayed



- Record the number of pulses and data of calibration in the calibration log
- Repeat for 5 runs

Analysis

A workbook template **Odometer Calibration.xlt** is available for the calculations[5]. It is located on the ROMDAS CD under menu **ROMDAS Software|Templates**. This template is shown below.



- Enter the data for each of the runs
- If the error tolerance is < 0.1% the 90 and 95% confidence intervals will show the word 'Pass'. If it is greater than 0.1% it will show 'Fail'. In this instance additional runs should be done.

For a discussion of the statistical basis for the above calculations please see Appendix B (Installing and Calibrating Roughness Meters).

Entering Results to Software

Every time a calibration survey is run the last calibration factor is stored for use. This value should be replaced by the mean factor calculated from the multiple runs above.

- Select **Setup|Calibrate|Calibrate Odometer|Enter Own Calibration Factor**
- Select the appropriate vehicle
- Enter the mean calibration factor

[5] A public domain spreadsheet program which can be used with the templates is provided on the ROMDAS CD. It is located under **Software Extras|Utilities|Applications|Spreadsheet Software**.

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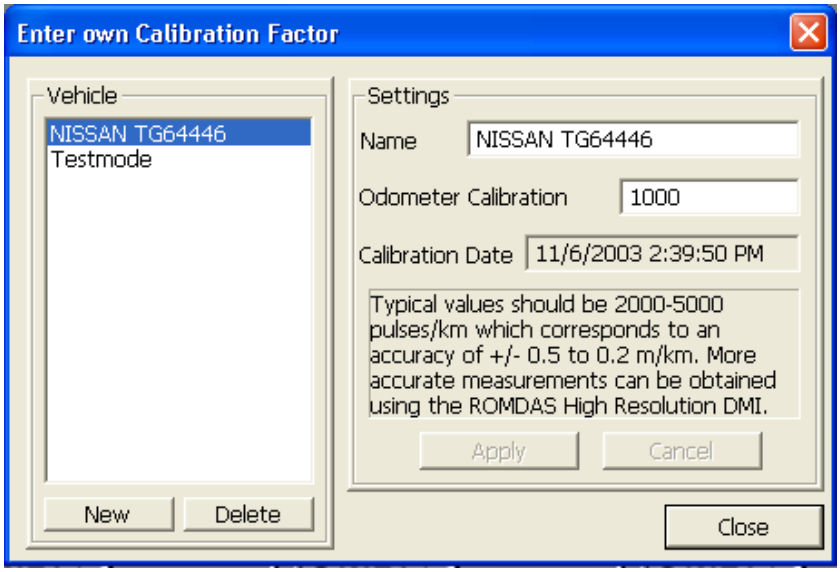

- Select **Apply**

5.3 Roughness Meter Calibration

Frequency

Before each major roughness survey or every 5000 km

Equipment Required

The following equipment are required:

- DMI and Roughness Calibration log **E012 Form 1** (see Appendix H)
- ROMDAS vehicle with DMI and roughness meters operating and computer installed
- Roughness calibration test sites (see Appendix B)

Calibration

Preparing the Vehicle

- Drive vehicle for minimum of 10 km to ensure that tyres are at operating temperature
- Check pressure with a tyre gauge and ensure that tyres are at their manufacturers recommended operating pressure.

Running the Calibration

- Start the ROMDAS software
- Select **Setup|Calibrate|Calibrate Roughness Meter**
- Enter the test section ID, description and select the vehicle to be calibrated
- Enter the length of the calibration section

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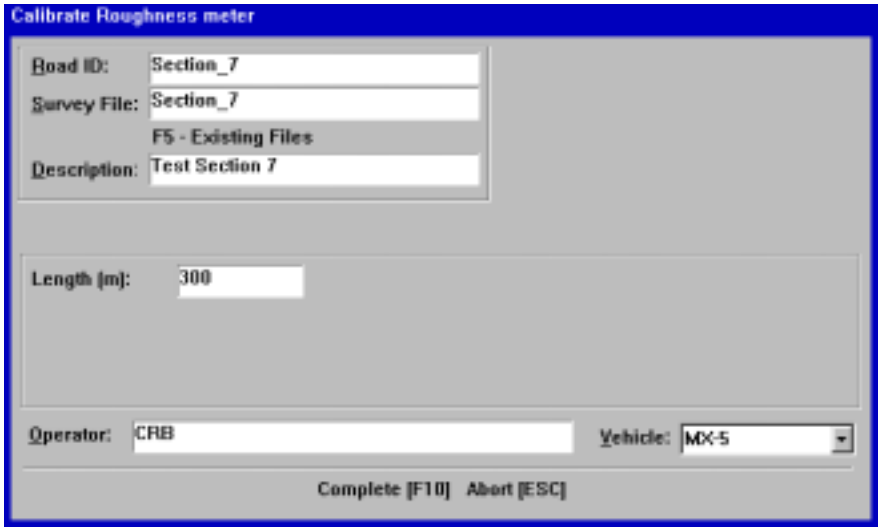
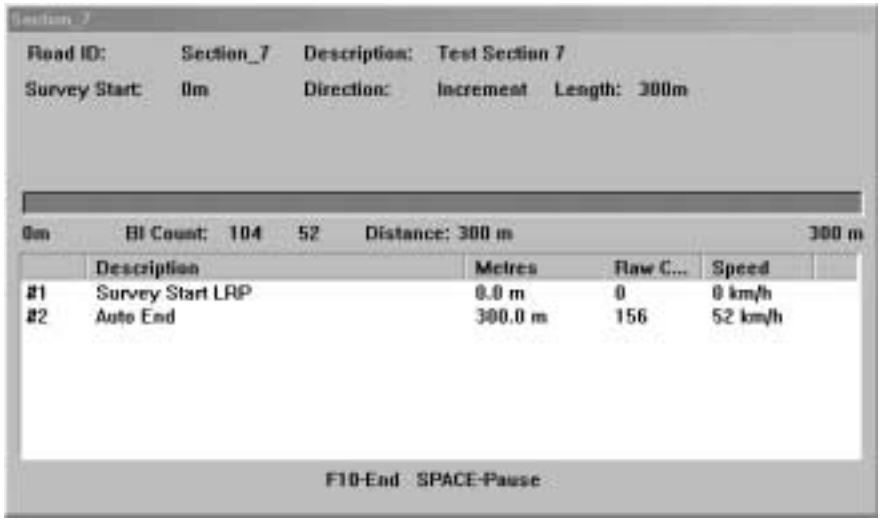


- Press **F10** to prepare the system to store the data
- Drive the vehicle to the appropriate speed[6].
- When the vehicle reaches the start of the test section press the **Space Bar** to start logging. The software will record for the distance entered (in the example above 300 m) and then automatically stop. The results will be displayed as shown below.



- Record the speed and raw count for each BI (*ie* 104 and 52 above)
- Perform at least three runs at each speed and check that the data are of an appropriate accuracy as described under analysis below. Perform additional runs as required.
- Repeat for each test section.

Analysis

A workbook template **Roughness Calibration.xlt** is available for the calculations[7]. It is located on the ROMDAS CD under menu **ROMDAS Software|Templates**. The **Data Sheet** in the workbook is shown below.

[6] One must calibrate the vehicle for each speed that is surveyed. Typically, these consist of low speeds (*eg* 30-50 km/h) and high speeds (*eg* 80 – 100 km/h).

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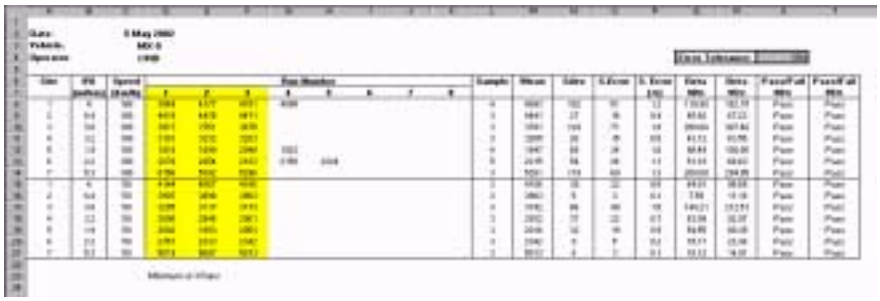


- Enter the roughness of the test section in IRI m/km in Column B.
- Enter the speed of the run in Column C.
- Enter the data for the roughness from each of the three runs in columns D to F.
- As described in Appendix B, if the mean is not statistically significant at 90 or 95% confidence intervals the data will show **Fail** in Column S or T. In this case, perform additional runs until **Pass** is shown. It may also be appropriate to delete outliers.

Note: If two bump integrators are used the data should be entered for each BI into the workbook. The above example is for a single BI.

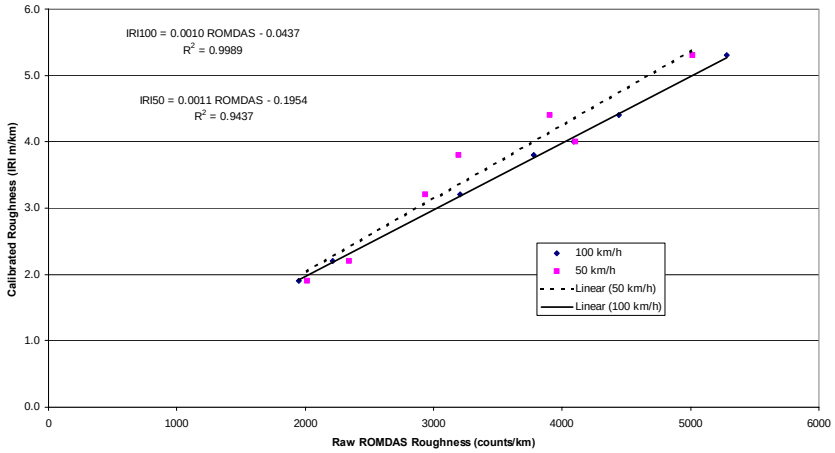
Roughness Calibration Equations

Roughness calibration equations are used to convert the raw survey roughnesses into calibrated IRI m/km. The template **Roughness Calibration.xlt** can be used to establish these equations.

The **Roughness Plot Sheet** shows the mean roughness from Column L plotted against the IRI from Column B. A linear or non-linear regression can be done on these data by right clicking on the series and selecting **Fit Trendline**.

The resulting data should be entered into the calibration log.

The figure below is an example of these equations.



7 A public domain spreadsheet program which can be used with the templates is provided on the ROMDAS CD. It is located under menu **Software Extras|Utilities and Applications|Applications| Spreadsheet Software**.

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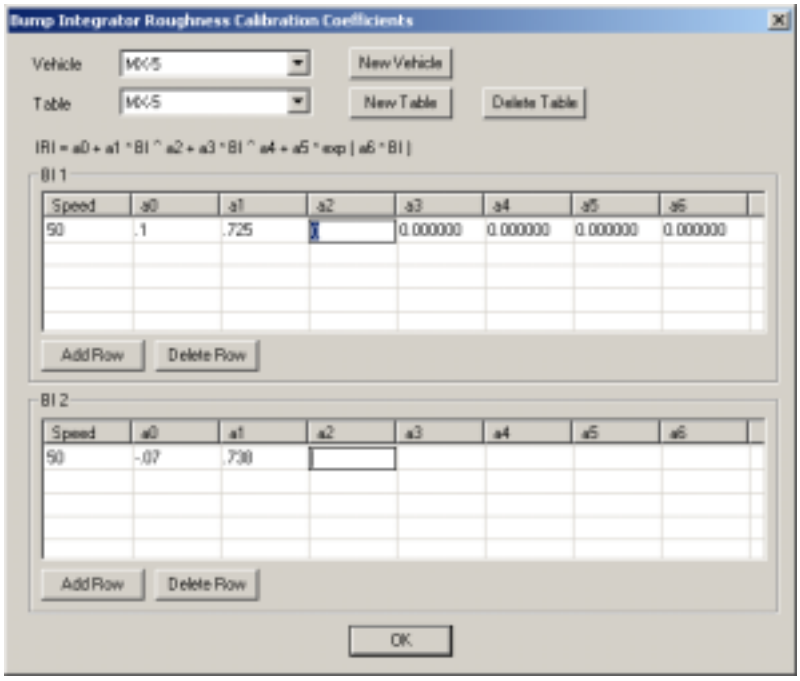
Defining Coefficients in ROMDAS

Having established the regression equations the coefficients can be entered in ROMDAS.

$IRI = a0 + a1\ BI^{a2} + a3\ BI^{a4} + a5 \exp(a6\ BI)$

- Select **Setup|Calibration Files|Edit Roughness Calibration Coefficients**
- Select the **Vehicle** which the coefficients will apply to.
- Enter the **Speed Value** that the coefficients apply to.
- Enter the coefficients for BI 1 and, if used, BI 2. The screen below shows the entries for the following equations to be applied at the calibration speed of 50 km/h:

  IRI-1 = 0.1 + 0.725 BI-1
  IRI-2 = -0.07 + 0.738 BI-2



Video Display Roughness Coefficients

The video overlay display can show the roughness. Instead of showing the actual IRI, the display is of a **Roughness Index** as expressed by a single equation, applied for all speeds. This is because the vehicle may be out of calibration during the survey and so any display of IRI may be incorrect.

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5.4 Laser Profiler Calibration

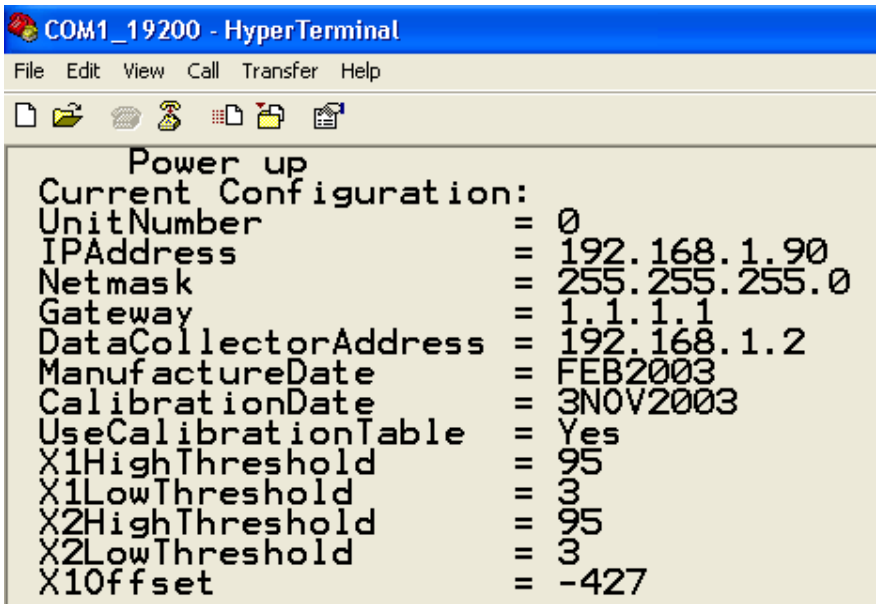
Frequency

Annually or sooner if not able to acceptable results in Elevation Tests

Calibration

Each laser unit is fitted with a calibration sticker containing the date of last calibration and the date of the next recommended re-calibration (12 months from last calibration). To ensure continued optimum performance of the unit re-calibration within the suggested dates is recommended.

If the calibration sticker has been removed then the last calibration date can be checked by connecting to the laser with the serial configuration cable and using the **config** command from Hyper Terminal. See Appendix C for details



Calibration is not possible by the user and the lasers need to be sent back to the manufacturer. Please contact DCL (info@ROMDAS.com) for details.

5.5 Transverse Profile Logger Calibration

Frequency

Before each TPL survey

Equipment Required

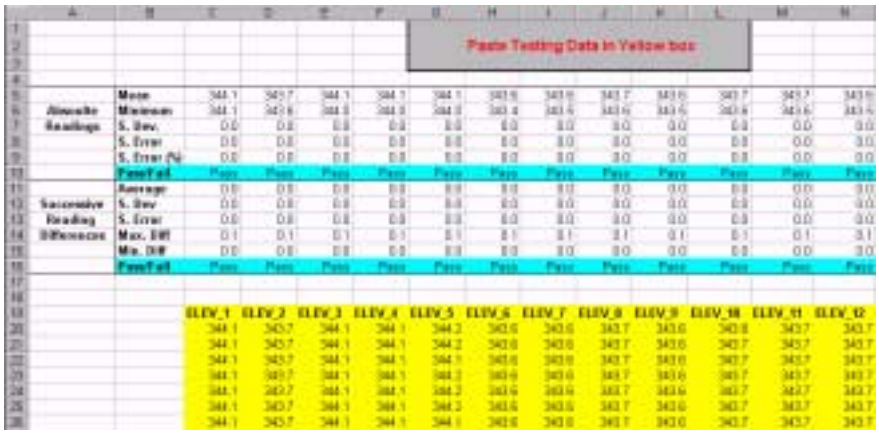
- TPL Calibration log **E012 Form 2**
- ROMDAS vehicle with TPL operating and computer installed
- TPL test trough. This can be made from a wooden frame with plastic sheeting, as shown below.

Calibration

- Fill the TPL trough with water
- Park the vehicle with TPL mounted over the trough on the level concrete floor of the garage
- Bounce the suspension of the vehicle to settle the suspension
- Select **Setup|Calibrate|Calibrate TPL|CREATE CALIBRATION DATA**
- Run the TPL for 1 minute

Analysis

A workbook template **TPL Calibration.xlt** is available for the calculations[8]. It is located on the ROMDAS CD under menu **ROMDAS Software|Templates**. The **Data Sheet** in the workbook is shown below.



The analysis performs two checks on the data:

[8] A public domain spreadsheet program which can be used with the templates is provided on the ROMDAS CD. It is located under menu **Software Extras|Utilities and Applications|Applications| Spreadsheet Software**.

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- **Absolute Readings:** The elevation readings (in mm) are checked to ensure that there are no missed readings (*ie* the minimum elevation is > 0), that the standard error is <= 1.0 mm, and that the standard deviation is <= 1.0 mm.
- **Successive Reading Differences:** These are the differences between successive elevation readings. The maximum difference must be <= 2 mm and the average <= 0.05 mm.

If any of the rules fail the **Pass/Fail** box will have the word 'Fail'. A check should be made of the TPL sensor which fails. Often, this only requires that the foam be repositioned.

To perform these checks the following procedure is followed:

- Process the data using the ROMDAS TPL data processing routines
- Open a new workbook using the Excel **TPL Calibration** template
- Open the file from the calibration in Excel
- Copy the data to the data section of the TPL Calibration workbook highlighted in yellow.
- Ensure that all data **Pass**.

5.6 Gyroscope Calibration

Frequency

Before every survey or when the gyroscope has been installed/re-installed in a vehicle.

Equipment Required

The gyroscope should be installed in the survey vehicle.

Calibration

When any gyroscope is stationary there will be a bias drift which is a function of temperature. At a fixed temperature it can be in the range of 2 – 4 degrees/h. The calibration consists of establishing a bias correction factor for this drift.

- Ensure that the gyroscope is at the typical operating temperature for the survey vehicle.
- Select **Setup|Calibrate|Calibrate Gyroscope|Gyro Autobias**
- With the gyroscope stationary, run an autobias test for 30 seconds
- Record the bias correction factor and the temperature

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6 Planning and Preparing for a Survey

6.1 Introduction

Overview

The importance of survey planning and preparation cannot be over-emphasised. Experience has shown that every hour spent planning a survey to ensure that it is executed smoothly can save up to 8 hours in post-survey data processing/corrections etc.

The **ROMDAS Data Collection Survey Quality and Management Plan** has been prepared by DCL to assist users in executing surveys. This report contains checklists, forms and other materials which will enhance survey quality. It is available on the ROMDAS CD along with workbooks that are used as part of the quality control.

This chapter focuses on the following components of survey planning and preparation:

- **Defining Keyboard Events.** Setting up the keyboard to record visually identified features during a survey.
- **LRP File Utilities.** Ways in which LRP files can be modified:
  - **Importing Data.** Creating an LRP file from an existing data source
  - **Reversing LRP Files.** Reversing the order of an LRP file to allow for the survey to be done in the opposite direction.
  - **Creating a Survey Route.** Combining individual LRP files into a single file representing a continuous survey route.
  - **LRP Definitions.** Short-cut definitions that can be used when defining LRPs in a survey
- **Survey ID Definition.** Creating a file which contains key survey data, such as the description and file name, so that when the operator enters a Survey ID all other data and survey options are correctly set.

6.2 Default Survey Settings

Overview

It is necessary to define the default survey settings before the survey can commence. These control the various settings and options available during the survey. These settings are described in Chapter 16.

6.3 Defining Keyboard Events

Overview

The principles behind keyboard rating were given in Section 4.4. The events are defined under the setting:

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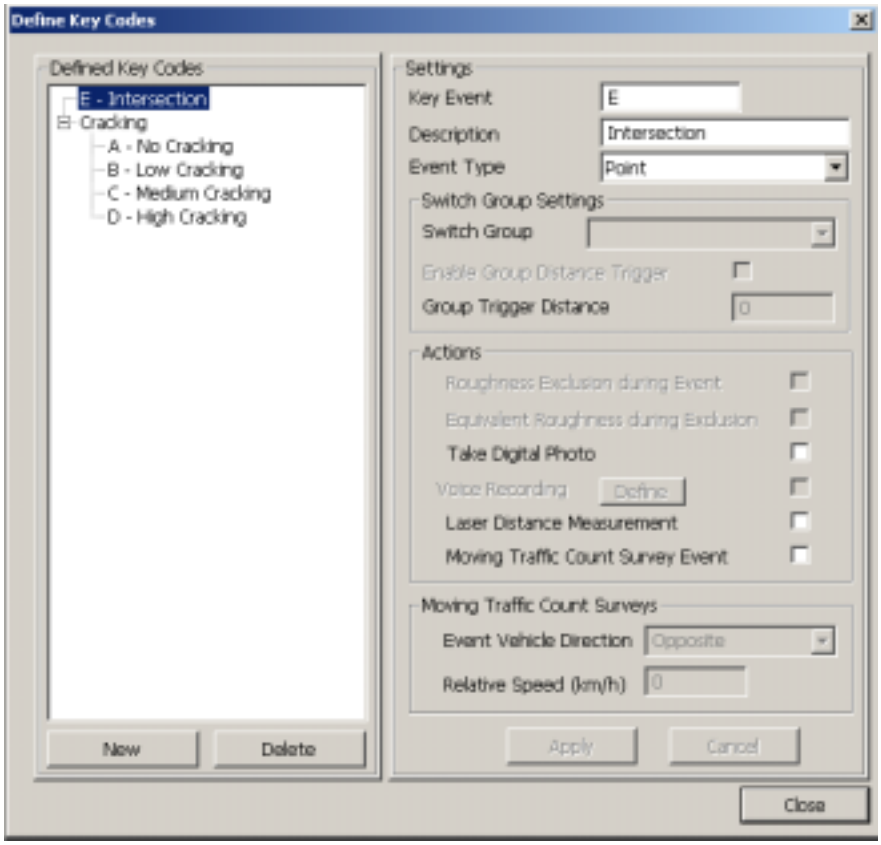
Setup|Survey Setup Files|Define Keycode Events

Selecting this entry gives the form displayed below.



Key Options

The keycode system can work with the keyboard set to be either have case sensitivity set to Yes or case sensitivity set to No. The default is Case Sensitivity set to No. With Case sensitive set to No the case of the letters are ignored, *ie* A = a; B = b; *etc*. if case sensitivity is Yes the A is different to a; B to b; *etc*. Using case sensitivity enables up to 120 keycodes to be defined compared to the 61 keys available with no case sensitivity. This setting is done under the **Setup|Options|Keycode Settings** menu (see Section 7.2). If using the computer keyboard for keycodes then generally the setting should be left at the default as it becomes very difficult for the operator to operate too many keys. If however more keycodes are needed and the ROMDAS rating keyboards are used (allowing different keys assigned to each case of the one letter) then the case sensitivity should be turned on. The screens (below) show the different options depending on the setting.

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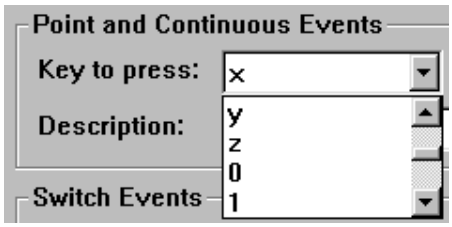
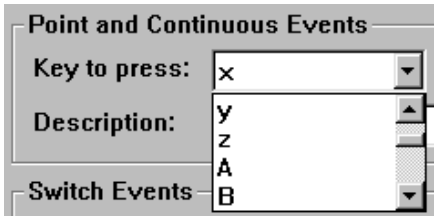


With Case Sensitivity set to NO



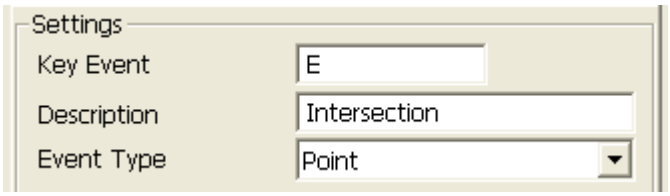
With Case Sensitivity set to YES

Point and Continuous Events

The same procedure is used to define a point or continuous event:

- Select **Point** event from the menu
- Select the key to activate the event
- Enter the event description

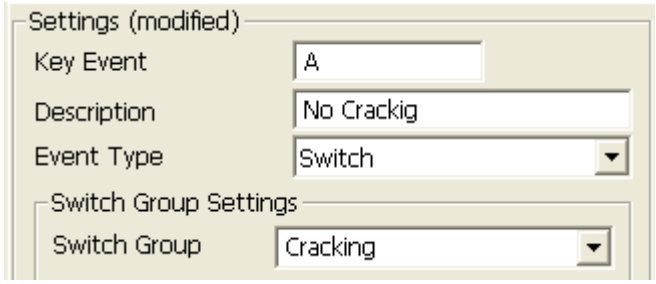
The screen below shows how the letter E would be assigned to a Point Event - Intersection.



Switch Events

Switch events are special types of continuous events. When one of the keys is pressed it cancels the previous key.

- Select **Switch** event from the menu
- Define a new **Switch Group Name or use a**
- Select the keys to press and provide a description for each



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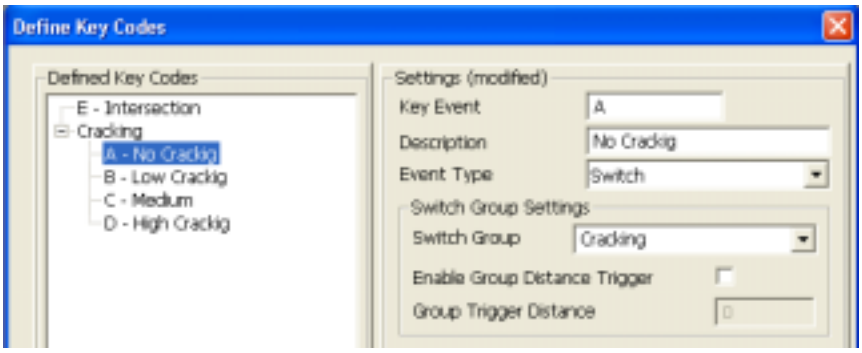
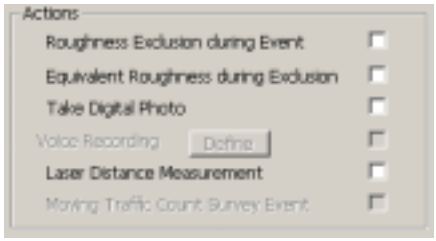
Reviewing Key Settings

The existing key settings are viewable in the list dialog on the left of the Settings form.



Settings

The **Active** group defines various setting options to be associated with individual keyboard events.



- **Roughness Exclusion during Event**. This option halts the roughness meter from recording while the event is selected. It is used, for example, to exclude recordings on bridges, during road works, *etc*. When activated, the **Equivalent Roughness during Exclusion** option is available. This is described in Chapter 9.
- **Take Digital Photo**. Indicates whether a digital photo is associated with the event. The type of digital camera can be defined for the event (see Section 3.10)
- **Voice Recording**. If selected, a voice recording is associated with the event. The user can define how the recording will be made (see Section 3.11).
- **Laser Distance Measurement**. If selected, a Laser Surveyor Measurement is associated with the event to give GPS co-ordinates of the object. The user can define how the recording will be made (see Section 7.1).
- **Moving Traffic Count Survey Event**. This defines the event as a moving traffic count survey event. When this is selected, the moving traffic count survey group box at the bottom right is activated. This is described below.

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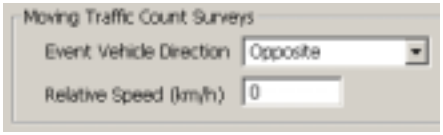
Moving Traffic Count Survey Events

Moving traffic count surveys are discussed in Chapter 13. In summary, every time the survey vehicle passes a vehicle the operator presses a key which has been associated with a moving traffic survey. When the data are processed, the times of observations and other data are used to estimate the AADT.

When an event is defined as a moving traffic count survey event, the screen to the right is activated. The direction of the vehicle can be entered and, optionally, its relative speed. The latter is used for an improved AADT estimate (see Chapter 13).



Laser Distance Measurement

This associates measurements with the laser surveyor option with the keyboard event. This will see the azimuth, inclination and distance of the event relative to the GPS position of the vehicle stored with the data. This would normally be used to record the GPS position of events of roadside furniture such as signs etc.

6.4 Importing LRP Data

Overview

As described in Chapter 4, LRP files are an integral component of ensuring survey data quality. LRP files are generally created through an LRP survey (see Chapter 8), but sometimes the data may be available in existing files, such as from a pavement management system. ROMDAS can import LRP files from other sources and put them into the required format for use in surveys.

Procedure

- Select **Setup|Survey Setup Files|LRP Utilities**
- Select **Import LRP Data**

6.5 Reversing LRP Files

Overview

LRP files are created with the LRPs in the order that they were surveyed in the original LRP survey. It is necessary to reverse the LRP files when the surveys are done in the opposite direction to the original LRP survey.

The table below shows the differences between original and reversed

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LRP files.

Original Direction			Reversed		
LRP	**Distance**	**Name**	**LRP**	**Distance**	**Name**
1	0	Km 0	4	0	Km 4
2	985	Km 1	3	992	Km 3
3	2005	Km 2	2	2012	Km 2
4	2997	Km 3	1	2997	Km 1

Procedure

- Select **Setup|Survey Setup Files|LRP Utilities**
- Select **Reverse LRP Files**
- Select the files to reverse

A new set of LRP files will be created. These will have the same names as the original LRP file, but with the suffix _O.

6.6 Creating Survey Routes

Overview

A survey route consists of a series of LRP files which will be driven continuously. For example, there may be files covering 0 - 10 km, 10 - 20 km and 20 - 25 km. It is proposed to drive this continuously as 0 - 25 km so a new LRP file is required which allows this.

A source table is created which includes the links to be included in a route. These **must** be continuous, for example it would not work in the above example to have 0 - 10 km and 20 - 25 km.

6.7 Pre-Defining LRP Entries

Overview

When defining LRP's in surveys the operators must type in a description of the LRP. To simplify the process and ensure consistency of the LRP descriptions it is recommended to use the Predefined LRP's. A list of LRP descriptions are each associated with a short-cut key. When the operator defines a LRP during the survey the complete LRP description is selected with the short-cut key. This feature is enabled under **Setup|Options|Location Reference Points**.

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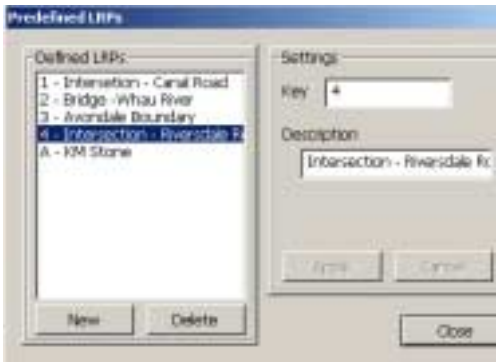
Defining

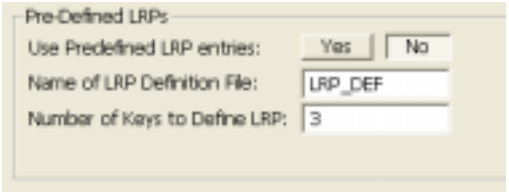
- Select **Setup| Survey Setup Files|LRP Utilities|Pre-Define LRPs**
- Enter the key for the short cut
- Enter the full LRP description



The screen to the right shows how entering '4' would have the LRP description stored as 'Intersection Riversdale Road '.

Customising

To use the Predefined LRP's during a survey the feature needs to be turned on under **Setup| Options | Location Reference Points**.



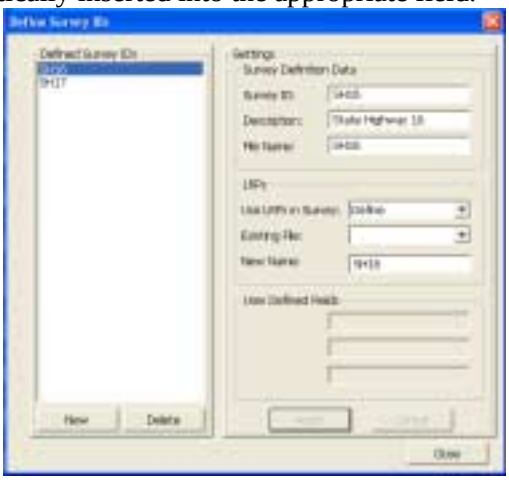
The **Name of LRP Definition table** can also be set here. The LRP definition tables are located in ..\ROMDAS\Setup\LRP Master.mdb.

6.8 Define Survey ID's

Overview

The Survey ID file is used to control the survey options. The data are typically generated from a standard database to ensure that the correct data are used during the survey. The operator enters the Survey ID and then the other data are automatically inserted into the appropriate field.

Under **Setup| Survey Setup Files | Define Survey Ids.** The screen to the right shows the data associated with each Survey ID:



- Survey description
- File name
- LRPs (Yes/No/Define)
- Existing or new LRP file name
- User defined fields (if activated as described in Section 16.2)

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As an example, the screen to the right shows the data that would have been entered to the survey definition screen after the user entered ‘SH16’. The description and file name were defined based on the entry in the screen given above.

7 Visual Keyboard Rating Surveys

7.1 Introduction

Overview

Visual keyboard rating surveys are done to record the locations of various features or 'events' along the road. This is done by assigning different events, such as pavement condition, roadside inventory, *etc*. events to keys on the computer and having an observer press the key when the event is observed. The position of the event, in terms of distance along the road and GPS co-ordinates (if GPS is in use) is recorded along with the description of the event.

Operational Considerations

The task of keyboard rating can be demanding so it is recommended that a separate operator be assigned this task. As described in Section 4.4, there are special 20 or 58 ROMDAS rating keyboards available which are designed to facilitate condition rating surveys (see below). Each key can be individually programmed to any key on the computer keyboard. These greatly simplify the visual rating process. Alternatively, a special dual keyboard adapter is available which will allow for 2 full keyboards to be run from a single computer.

20 Key Keyboard

58 Key Keyboard

Dual Keyboard Connector

Appendix G describes how the rating keyboards are programmed.

The rating or dual keyboards are connected to the external keyboard port on the data collection computer and the data are logged when the keys are pressed.

Types of Events

The definition of keyboard events was described in detail in Section 4.4. Before the survey starts the events must be defined as point or continuous events:

- a **point event** is something which exists at a single point in space, such as traffic signs or LRPs; or,
- a **continuous event** is something which exists over a section, such as pavement condition. Continuous events have two chainages: a

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beginning and end chainage.

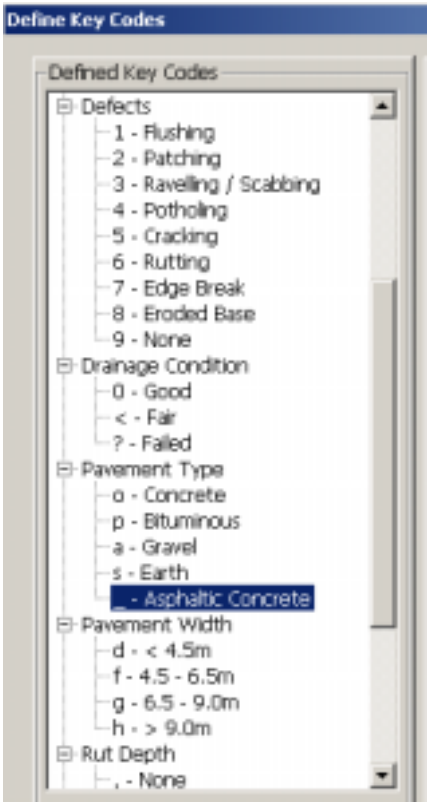
There is a special type of continuous event called a **switch** event. This can be understood as a series of continuous events. For example, one may define a ranking for pavement condition from 0 to 5. These are continuous events so one would normally have to press two keys when changing; one to end the previous condition and one to apply to the new condition. Switch events remove the need to press two keys. When the second key is pressed the first event is cancelled[9].

Switch events are allocated into Switch Groups. Each Switch Group contains a set of related mutually exclusive continuous events.

You can only have one event activated in each group at any one time and another key press of any event in that switch group will turn off the currently activated key and activate the new one in that group.

In the example on the right the Switch Groups are

- Defects
- Drainage Condition
- Pavement Type
- Pavement Width
- Rut Depth



Most Switch Groups will need to be recorded for the whole road section being surveyed and will need to be activated before the survey starts by using Preliminary Keycodes.

Continuous events and switch events are recorded the same in the keycode table with a start and end chainage.

Laser Surveyor

If you require the accurate positions of your keyboard events we recommend that you use the ROMDAS Laser Surveyor option. This uses a hand held laser distance measurement device with an integrated compass and

[9] Normally, one has events that apply continuously along a section of road. For example, there will always be either no cracking or a level of cracking. ROMDAS defaults to having the user switch only between switch events; you cannot have 'no' event. However, this can be overruled in the keycode event setup options using the **Turn off switch Event with Second Push** parameter.

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inclinometer for accurate positioning.

These are used to take a 'shot' of the event and the data is recorded by ROMDAS in the data file. These data can then be used with the GPS co-ordinates to obtain a precise location of the event. When coupled with digital photos this offers an excellent way of obtaining the detailed locations of the events.

Special Features

During keyboard surveys it is possible to collect additional data:

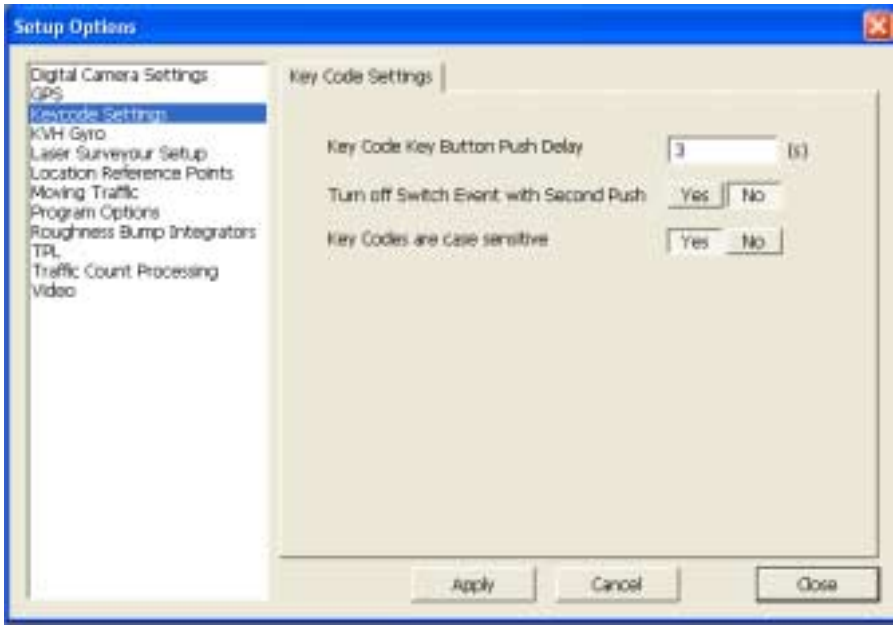
- **Digital Photographs**. When the vehicle is stopped a digital photograph can be taken of the roadside event. The operator enters the frame number and this is stored along with the photograph name in the file.
- **Voice Recordings**. The operator can enter comments which are stored as a .WAV file.

These are described in Sections 3.10 and 7.5.

7.2 Keycode Setup Options

Keycode Setup Options

The menu at **Setup Options|Keycode Settings** is used to define the following global keycode settings.



- **Keycode Key Button Push Delay**. This is the time delay (in s) for pressing a keycode event key twice. It is used to prevent incorrect readings due to the same key being pressed twice by mistake.
- **Turn off Switch Event with Second Push.** Switch events are usually

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used to apply a condition rating which applies to all sections of road. Thus, if the condition is being rated from 0 to 5 it must always have a value, even if it is 0. Under certain situations users may wish to have sections of road not assigned any value. In this instance this option should be set to Y and the switch group will be turned off with the second key push of any member of that switch group.

- **Keycodes are Case Sensitive**. It is possible to have 61 or 119 keycode events defined. For most applications 61 is more than sufficient so this is the system's default. If additional keycode events are required this option should be set to Y.

7.3 Executing the Survey

Defining Survey Data

When the **Surveys** option is selected the standard survey input screen shown below is displayed. The keyboard survey is always enabled and can be used with any combination of surveys, the standard survey input screen shown below is displayed. The data entered are as follows:

- **Survey ID**: A unique code identifying the survey.
- **Survey File**: The name of the file where the data are stored. This defaults to the Survey ID.
- **Description**: A description of the survey.
- **LRP Reset**: How LRPs are used in the survey (No/Yes/Define).
- **LRP Data Files**: The name of the data file with the LRPs (if 'Yes' selected for LRP reset).
- **Start** [P7]**Chainage**: The chainage along the road where the survey is starting. This will usually be 0. It would be non-zero if the survey starting part way along the road.**Direction**: This indicates if the measurements are increasing or decreasing. For example, a road section starting at 0 and going to 1000 m is increasing, with the other direction being classified as decreasing.
- **Operator:** The name of the operator for the survey.
- **Vehicle:** The vehicle used in the survey. The data are selected for a list based on the vehicle calibrations.

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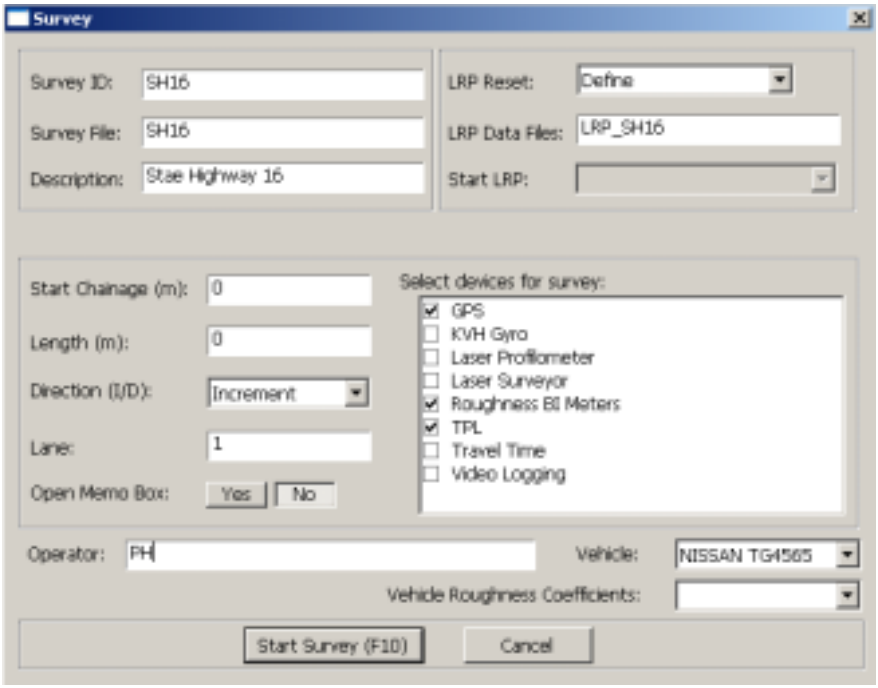
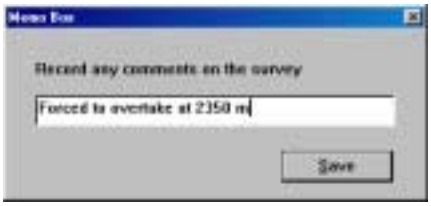


There are a number of optional settings which allow for additional instruments to be used in the survey (TPL, video logging, GPS, Laser Profiler). For these to be used it is necessary to enable them as described under setting up the system (see Chapter 16).

The **Open Memo Box** option allows user to enter comments on the survey when the survey ends. This data is stored with the survey header. At the completion of the survey a memo box will be opened The default setting for this option is controlled under **Setup|Options|Program Options**.



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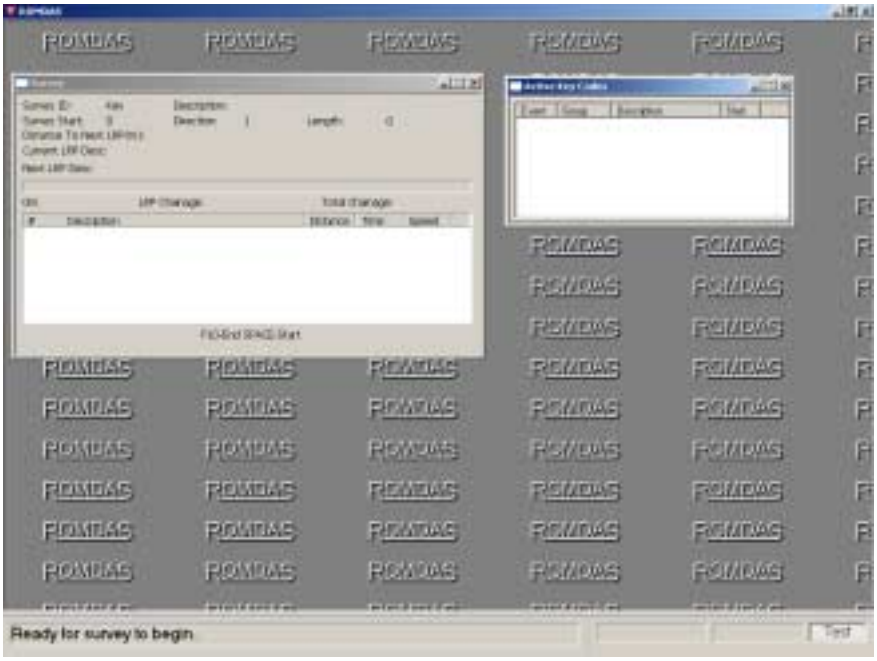
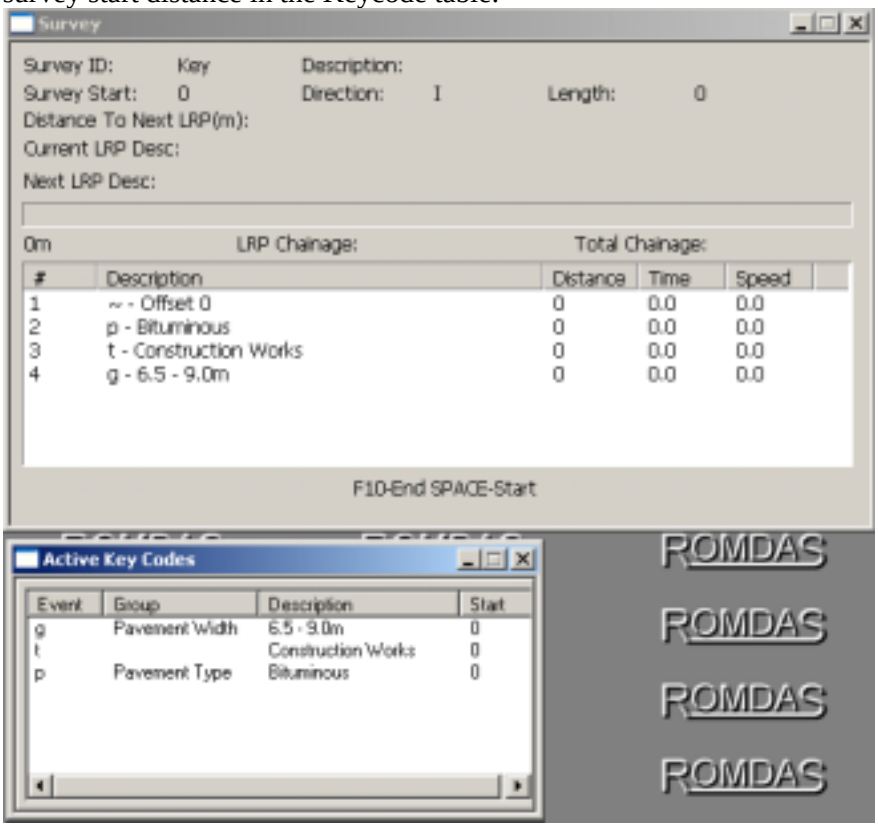
Once all the survey data are entered select F10. The screen below will be shown. To start the survey press the **Space Bar**.



Preliminary Keycodes

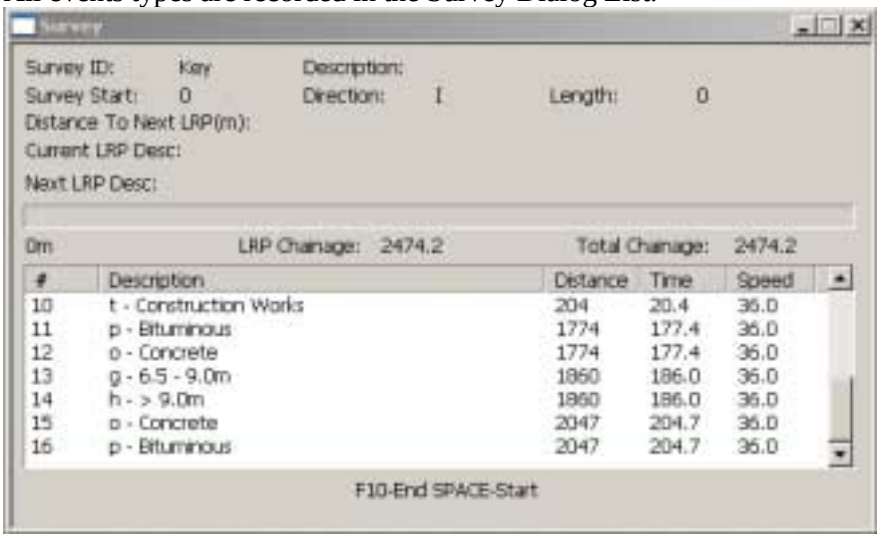
Some events (usually switch events) will need to be activated from the start of the section. Any Keycode can be pushed before the **Space Bar** to start the survey. These preliminary keycodes will all be recorded at the survey start distance in the Keycode table.


Survey
Survey ID: Key Description:
Survey Start: 0 Direction: I Length: 0
Distance To Next LRP(m):
Current LRP Desc:
Next LRP Desc:
0m LRP Chainage: Total Chainage:
Description Distance Time Speed
1 ~ - Offset 0 0 0.0 0.0
2 p - Bituminous 0 0.0 0.0
3 t - Construction Works 0 0.0 0.0
4 g - 6.5 - 9.0m 0 0.0 0.0
F10-End SPACE-Start
Active Key Codes
Event Group Description Start
g Pavement Width 6.5 - 9.0m 0
t Construction Works 0
p Pavement Type Bituminous 0
ROMDAS

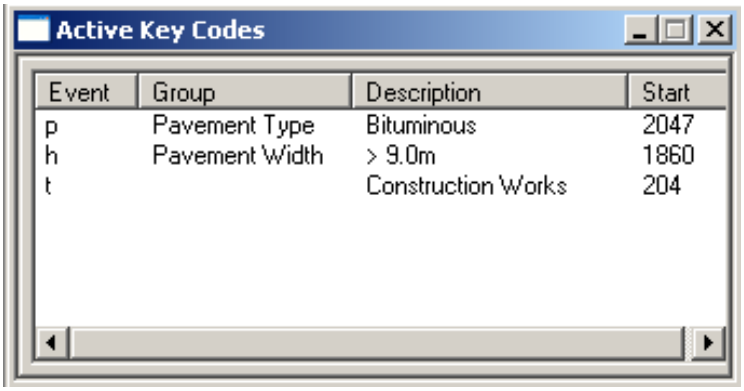
During the Survey

As events are observed the keys are pressed. The location (in terms of the chainage) is displayed for the event.

All events types are recorded in the Survey Dialog List.


Survey
Survey ID: Key Description:
Survey Start: 0 Direction: I Length: 0
Distance To Next LRP(m):
Current LRP Desc:
Next LRP Desc:
0m LRP Chainage: 2474.2 Total Chainage: 2474.2
Description Distance Time Speed
10 t - Construction Works 204 20.4 36.0
11 p - Bituminous 1774 177.4 36.0
12 o - Concrete 1774 177.4 36.0
13 g - 6.5 - 9.0m 1860 186.0 36.0
14 h - > 9.0m 1860 186.0 36.0
15 o - Concrete 2047 204.7 36.0
16 p - Bituminous 2047 204.7 36.0
F10-End SPACE-Start

The currently activated Continuous and Switch events are also displayed in the Active Keycodes Dialog. A Continuous event will stay on until the key is pressed for the second time, indicating the end of the event.
A Switch Event will stay on until another Switch event in that Switch Group is pressed (or if the current key is pressed for a second time and the option **Turn off Switch Events with Second Key Push** is turned ON)


Active Key Codes
Event Group Description Start
p Pavement Type Bituminous 2047
h Pavement Width > 9.0m 1860
t Construction Works 204

In the above Active Keycode dialog the first two events are Switch keys (as they are part of the Pavement Type and Pavement Width switch groups). The Construction Works event is continuous as it has no entry in the Group field.

Ending the Survey

At the completion of the survey press the **F10** key. The screen below will be shown.

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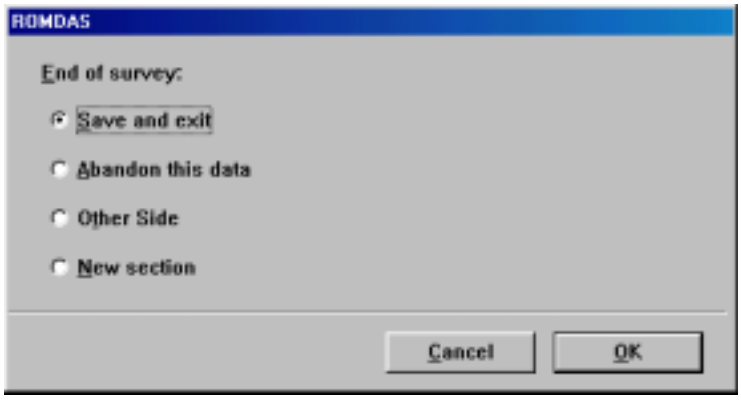


The **Other Side** option enables for the road to be surveyed in the opposite direction (see Section 4.5). **New Section** allows for another section to be surveyed immediately.

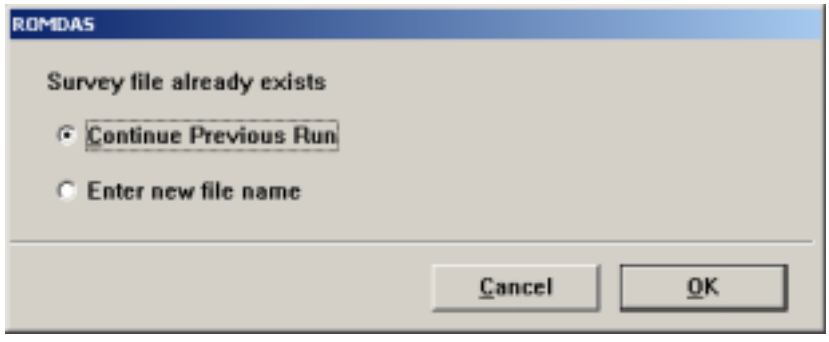
Example of Data

An example of the key data from the survey is shown below. A full description of the data is given in Chapter 17.

RECTYPE	EVENT_DESC	EVENT	EVENT_START	EVENT_END
11	AC Pavement	a	18	
11	Bridge	b	40	230
11	Cracking - Low	c	942	1013
11	Cracking - Medium	d	1013	1062
11	Cracking - High	e	1062	1282

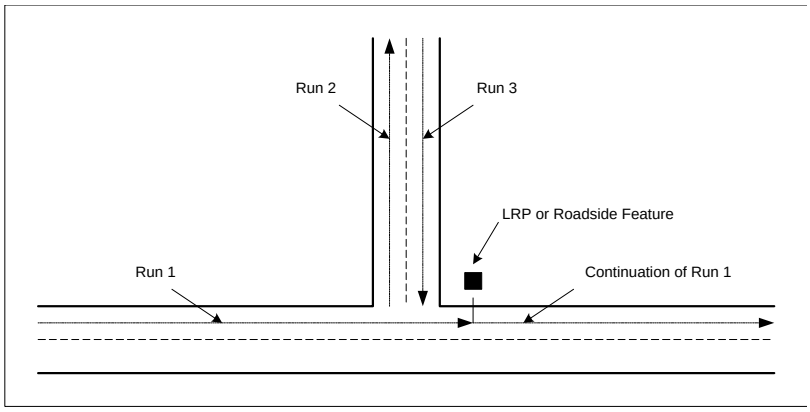
Continuing Previous Surveys

If you select the same ID as a previous survey the options below will be given:

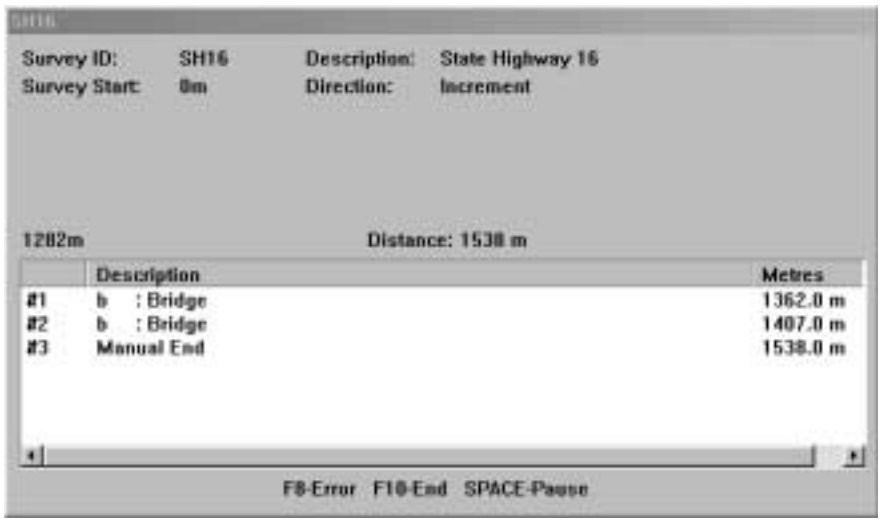


Continue Previous Run

Selecting **Continue Previous Run** sees the previous run continued. This option is usually used for the situation described in Section 4.6 and shown below.



An example of this is shown below. At the left of the survey screen the end chainage from the previous survey is shown (*ie* 1282 m in the example below). This is the start chainage for the continuation.


Survey ID: SH16 Description: State Highway 16
Survey Start: 0m Direction: Increment
1282m
Distance: 1538 m
Description Metres
#1 b : Bridge 1362.0 m
#2 b : Bridge 1407.0 m
#3 Manual End 1538.0 m
F8-Error F10-End SPACE-Pause

The new data are appended to the end of the file as shown below.

RECTYPE	EVENT_DESC	EVENT	EVENT_START	EVENT_END
11	AC Pavement	a	18	
11	Bridge	b	40	230
11	Cracking - Low	c	942	1013
11	Cracking - Medium	d	1013	1062
11	Cracking - High	e	1062	1282
11	Bridge	b	1362	1407

Enter new file name

The survey other side option will see the chainages decreased from the end chainage of the previous run.

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7.4 Digital Photographs

Overview

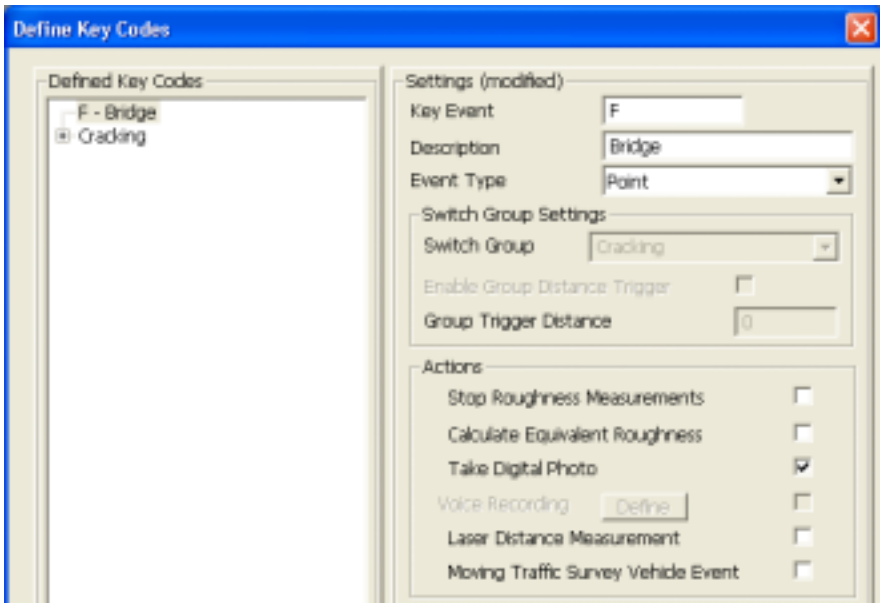
Digital photographs are used to record the keycode features.

Setting Up the Camera

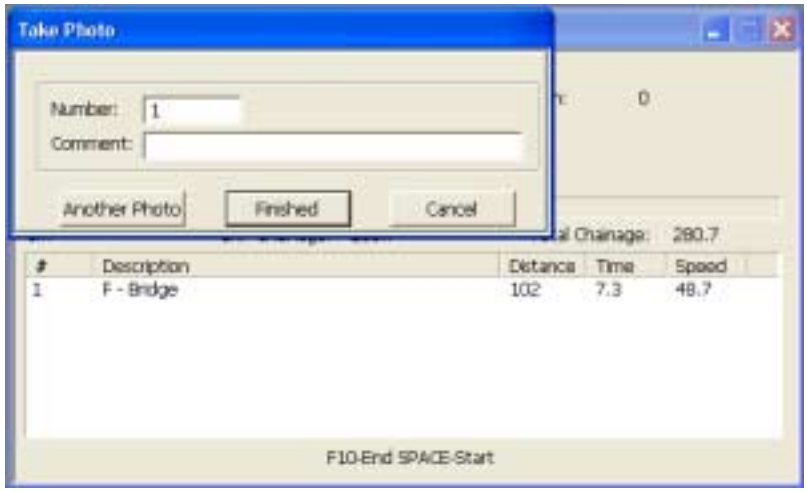
The setting up of digital cameras is described in Section 3.9.

Setting Up the Keyboard Event

The digital photograph must be associated with a keyboard event with a keyboard event (see Section 6.3). The screen below shows how a digital photograph would be associated with a bridge event.



During the Survey



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When the Keycode event key activated the Take Photo dialog above appears allowing one or more digital photographs of the event to be logged. For each photograph the incremental photo number is displayed. This can changed if required. A comment can be entered if required. If more than one photograph of the event is required then the **Another Photo** button should be used else select **Finished** to exit the dialog.

Example of Output

An example of the photo data from the survey is shown below. A full description of the data is given in Chapter 17.

	CHAINAGE	SET_NUMBER	PHOTO_NUMB	COMMENT	FILE_NAME
▶	101.9	1	1		Sony00001.jpg
	101.9	1	2		Sony00002.jpg
*					

	CHAINAGE_ST	CHAINAGE_EN	EVENT	EVENT_DESC	PHOTO_SET
▶	102	102	F	Bridge	1
*					

7.5 Voice Recordings

Overview

Voice recordings are used during surveys to store audio data for future playback. It is typically used for storing details on roadside features such as bridges, environmental or social features.

Setting Up for Voice Recording

The setting up of voice recordings is described in Section 3.11.

Setting Up the Keyboard Event

The voice recording must be associated with a keyboard event (see Section 6.3). The screen below shows how a voice recording would be associated with a point event for a bridge.

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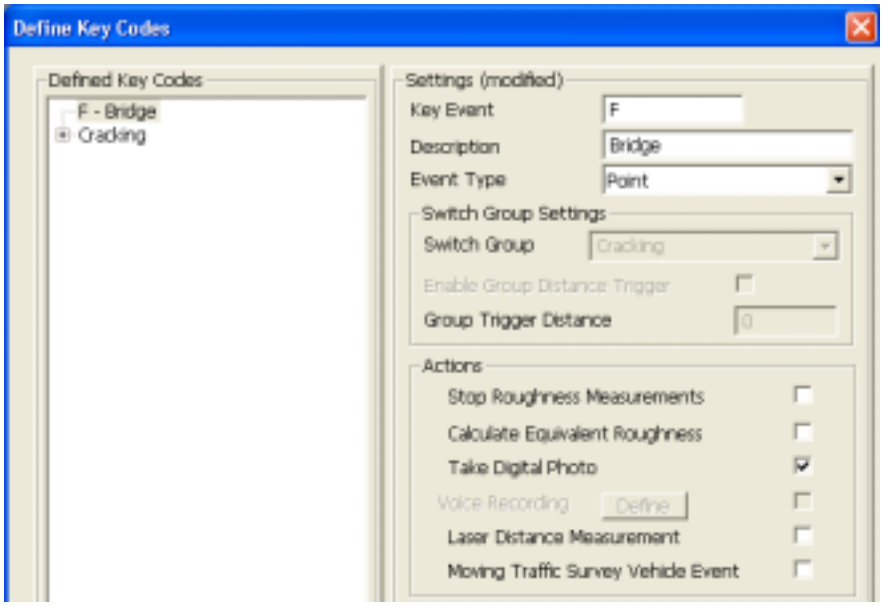
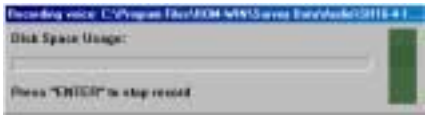


During the Survey

It is recommended that a remote microphone be used to improve the quality of the recordings.

Using internal recording, when the key is pressed, the window to the right will be displayed as the data are recorded to a Windows .WAV file.



Example of Output

The voice files are stored as the Survey ID with the suffix –x.wav. The value for x is the sequence of the recordings (1 for first; 2 for second, *etc.*). The table below is an example of the output from a survey.

RECTYPE	EVENT_DESC	EVENT	VOICE_NUM	VOICE_NAME
11	Trees adjacent to road	t	1	SH43-1.wav

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8 Location Reference Point Surveys

8.1 Introduction

Overview

The Location Reference Point (LRP) Survey is used to establish the chainages of the various LRPs. As discussed in Section 4.2, these LRPs are any permanent fixture adjacent to the road, for example km posts. By having regular LRPs the data collected in the roughness survey can be accurately related to the same sections of road, even when the survey is conducted in different years.

The LRP Survey allows the operator to record both the chainage of the LRPs and their identifiers. At the same time, they can do keyboard rating of events and store GPS data if the vehicle is fitted with a GPS receiver.

Establishing LRPs

LRPs can be surveyed using either a dedicated LRP survey or during another survey, such as a roughness survey.

It is **strongly recommended** that LRPs be defined in a separate survey to the roughness survey. There are two principal reasons for this:

- the LRPs are the basic description of your network and they should be located as accurately as possible. Since the roughness vehicle will generally be travelling at a speed above 30 km/h such accuracy is difficult to achieve;
- if you have existing markers, such as kilometre stones, it is often necessary to stop the vehicle to read the marker, to remove grass or debris which may be obscuring it, or even to find the marker. This is impossible during a roughness survey.

LRP Records

During LRP surveys it is advisable to also take digital photos of the LRPs and record LRP diagrams. These can be retrieved in computer applications such as the HDM-4 Information Management System (www.hdm-ims.com) and will ensure that the LRPs can be found in future surveys. The figures below are examples of this from an LRP survey in Samoa.

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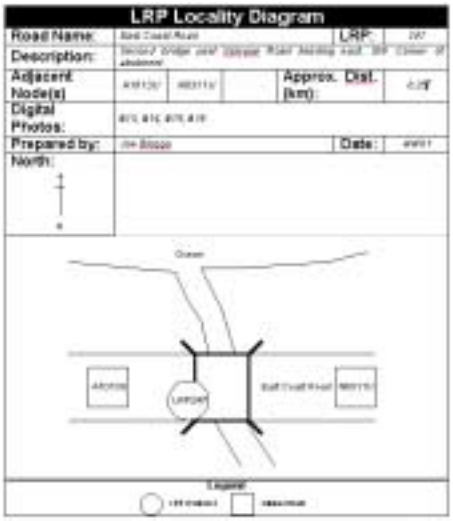
LRP on Culvert

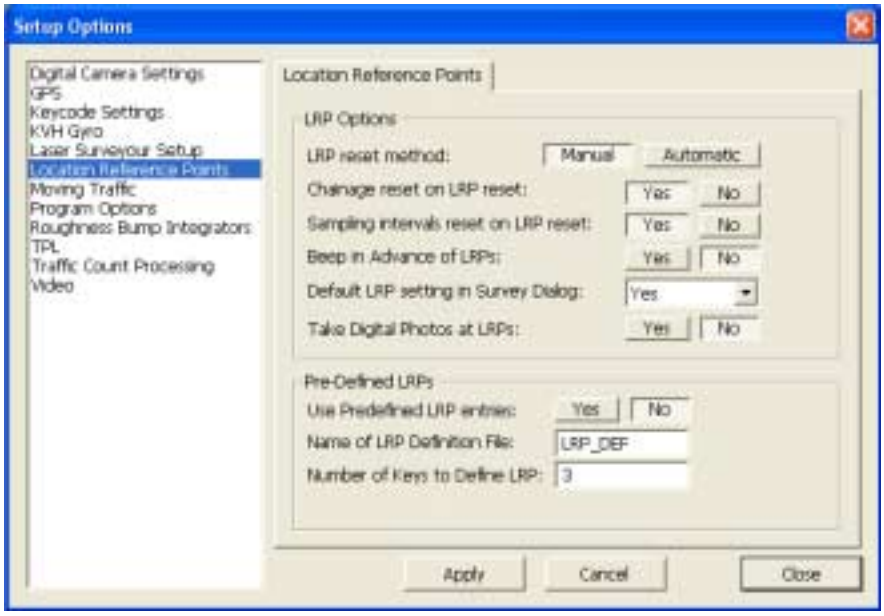
LRP on Bridge



LRP Diagram

8.2 LRP Setup Options

LRP Setup Options



- **LRP Reset Method**: This option determines how LRP resets are to be recorded. Manual resets mean that the operator must press the ESC key; Automatic resets automatically reset the readings when the chainage corresponds to that of the LRP. It is recommended that these resets be MANUAL (M) since there will always be slight differences in the chainages between surveys (see Section 4.2).
- **Chainage Reset on LRP Reset**: If set to **Yes** (the default) the survey chainage is reset to zero as an LRP location is marked all subsequent chainages are then relevant to the Last LRP.
- **Sampling Intervals reset on LRP Reset**: If set to **Yes** (the default) is

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yes as normally the sampling intervals should be reset at LRP's

- **Beep in Advance of LRP's**: Setting this to "Y" warns the operator through audible beeps that an LRP is approaching. Beeps are given every 25 m before an LRP, starting at 100 m. It is recommended that this be enabled.

Default LRP Settings in Survey. This option defines whether or not to default to using LRPs. The options available are:

Yes	Use an existing LRP file
No	Don't use LRP's
Define	Add or define new LRPs

If you are defining LRPs (D), consider using the LRP Definition option (see Section 6.7). This allows you to define a short keycode associated with a longer description, making it easier to ensure consistency during the survey.

- **Take Digital Photos at LRP's**: This option is used to assign digital photo numbers to specific LRPs. In the survey the vehicle will stop adjacent to the LRP and take a photo with a digital camera. Upon noting an LRP the operator will record the LRP data as in the standard survey. If this option is selected they will be asked to enter the digital photo number.
- **Use Predefined LRP entries**: As described in Section 6.7, it is possible to predefine the LRP descriptions. This means that during the survey the operators only need to enter a short code to insert the full LRP description entry. Setting this option to Y means that these definitions can be accessed when the ALT key is pressed during the survey.
- **Name of LRP Definition Table**: The default table name in the …/ROMDAS/Setup/LRP.MDB file is LRP_DEF. This can be changed by entering another table name.

8.3 Executing the Survey

Defining Survey Data

When the **Surveys** option is selected, the standard survey input screen shown below is displayed. The data entered are as follows:

- **Survey ID**: A unique code identifying the survey.
- **Survey File**: The name of the file where the data are stored. This defaults to the Survey ID.
- **Description**: A description of the survey.
- **LRP Reset**: How LRPs are used in the survey (No/Yes/Define).
- **LRP Data Files**: The name of the data file with the LRPs (if 'Yes' selected for LRP reset).
- **Start** [P10]**Chainage**: The chainage along the road where the survey is starting. This will usually be 0. It would be non-zero if the survey starting part way along the road.
- **Direction**: This indicates if the measurements are increasing or decreasing. For example, a road section starting at 0 and going to 1000 m is increasing, with the other direction being classified as decreasing.
- **Operator:** The name of the operator for the survey.
- **Vehicle:** The vehicle used in the survey. The data are selected for a

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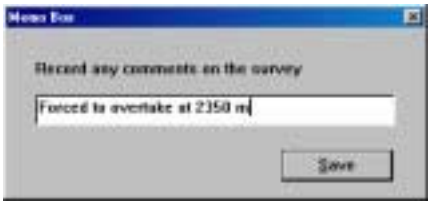
list based on the vehicle calibrations.

There are a number of optional settings which allow for additional instruments to be used in the survey (TPL, video logging, GPS, GripTester). For these to be used it is necessary to enable them as described under setting up the system (see Chapter 16).

The **Open Memo Box** option allows user to enter comments on the survey when the survey ends. This data is stored with the survey logs. At the completion of the survey a memo box will be opened The default option is controlled under **Setup|Options|Program Settings**.



Starting the Survey

Once all the survey data are entered select F10. The screen below will be shown. Since LRP surveys must always start at an LRP, the start name must be entered to continue.

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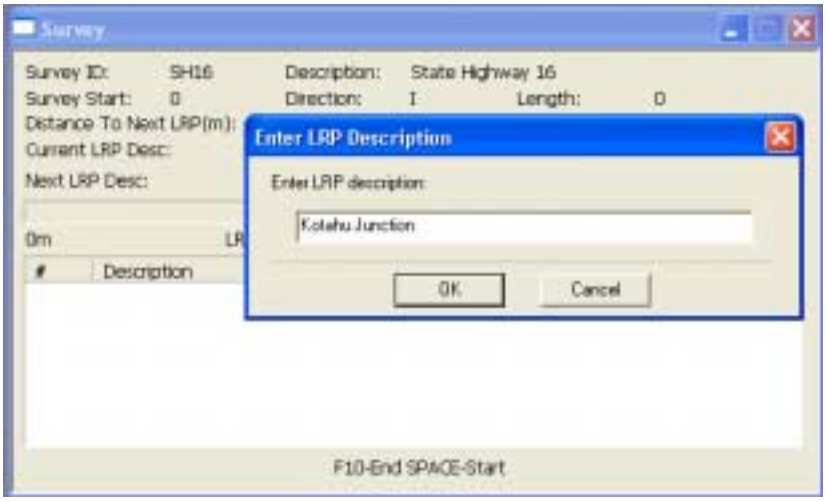
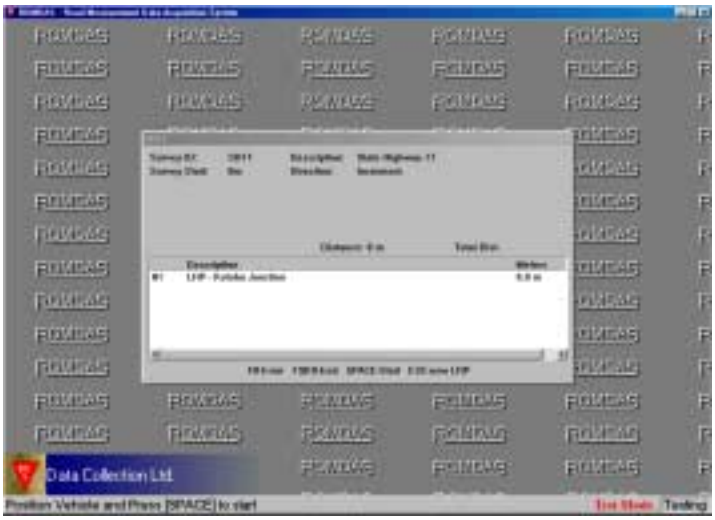
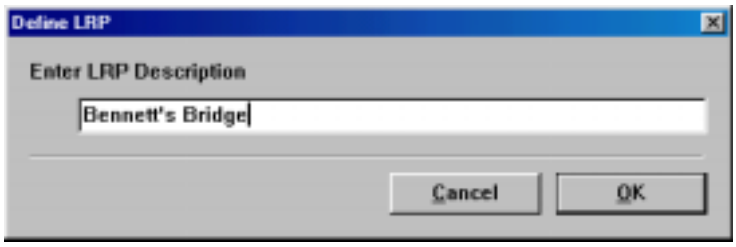


The following screen is displayed. Press the **Space Bar** to start surveying.



During the Survey

When an LRP is reached press the **ESC** key. The window below will open and the LRP description is entered.



The display will list the distance from the last LRP as well as the total distance travelled (see below).

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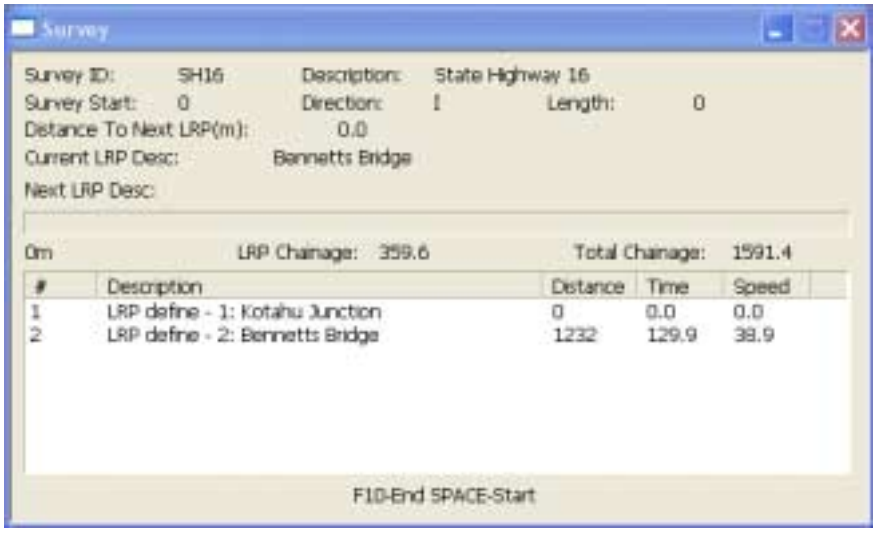
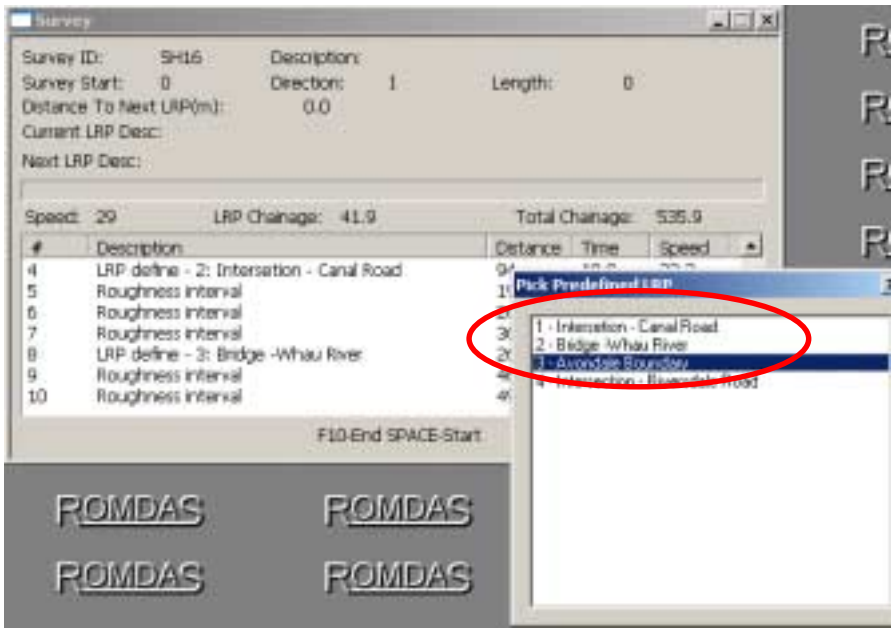

Survey
Survey ID: SH16 Description: State Highway 16
Survey Start: 0 Direction: 1 Length: 0
Distance To Next LRP(m): 0.0
Current LRP Desc: Bennetts Bridge
Next LRP Desc:
0m LRP Chainage: 359.6 Total Chainage: 1591.4
Description Distance Time Speed
1 LRP define - 1: Kotahu Junction 0 0.0 0.0
2 LRP define - 2: Bennetts Bridge 1232 129.9 38.9
F10-End SPACE-Start

Using Predefined LRP's

Instead of using the ESC key to mark the LRP and have to type in the LRP description you can use the Predeined LRP's option to automatically define the LRP. You must have the required LRP descriptions entered into the Predefined LRP definition table (see Section 6.7) and the LRP Predifintion feature enabled in the **Settings | Options | Location Reference Points** menu.


Survey ID: SH16 Description:
Survey Start: 0 Direction: 1 Length: 0
Distance To Next LRP(m): 0.0
Current LRP Desc:
Next LRP Desc:
Speed: 29 LRP Chainage: 41.9 Total Chainage: 535.9
Description Distance Time Speed
4 LRP define - 2: Intersection - Canal Road
5 Roughness interval
6 Roughness interval
7 Roughness interval
8 LRP define - 3: Bridge -Whau River
9 Roughness interval
10 Roughness interval
F10-End SPACE-Start
Pick Predefined LRP
1 - Intersection - Canal Road
2 - Bridge -Whau River
3 - Avondale Roundabout
ROMDAS
ROMDAS
ROMDAS
ROMDAS

Pushing the **ALT** key will bring up the **Pick Predefined LRP** list. Then the Predefined LRP short-cut key followed by the Enter key can be used to select the required LRP Description

Ending the Survey

At the completion of the survey press the **F10** key. If you end at an LRP press the **F9** key. You will then be given a box to enter the LRP name.

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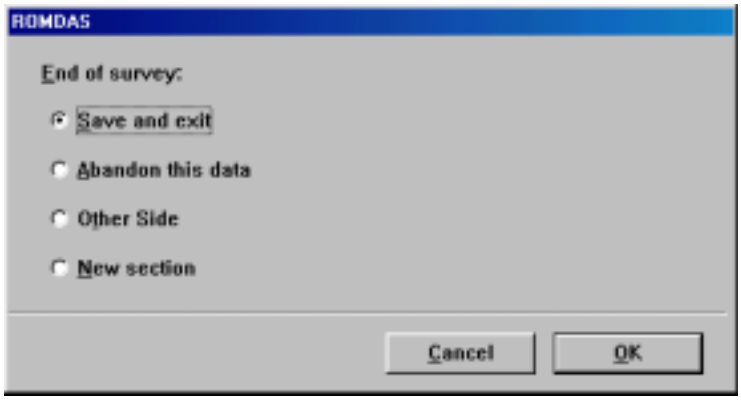
The end of survey screen below will then be shown.



The **Other Side** option enables for the road to be surveyed in the opposite direction (see Section 4.5). **New Section** allows for another section to be surveyed immediately.

Example of Data

An example of the key data from the survey is shown below. A full description of the data is given in Chapter 17.

Continuing Previous Surveys

The **continue previous surveys** works in the same manner as described in Section 7.2 for keyboard rating surveys.

8.4 Digital Photographs

Using Digital Photographs

A description of the use of digital photographs is given in Section 7.4

8.5 Voice Recordings

Using Voice Recordings

A description of the use of digital photographs is given in Section 7.5.

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9 Roughness Surveys with Bump Integrators

9.1 Introduction

Overview

Roughness surveys are used to record the roughness over a **sampling interval**. Typically 100 m, the roughness can be recorded using one or two bump integrators. During the roughness survey additional data can be recorded, such as:

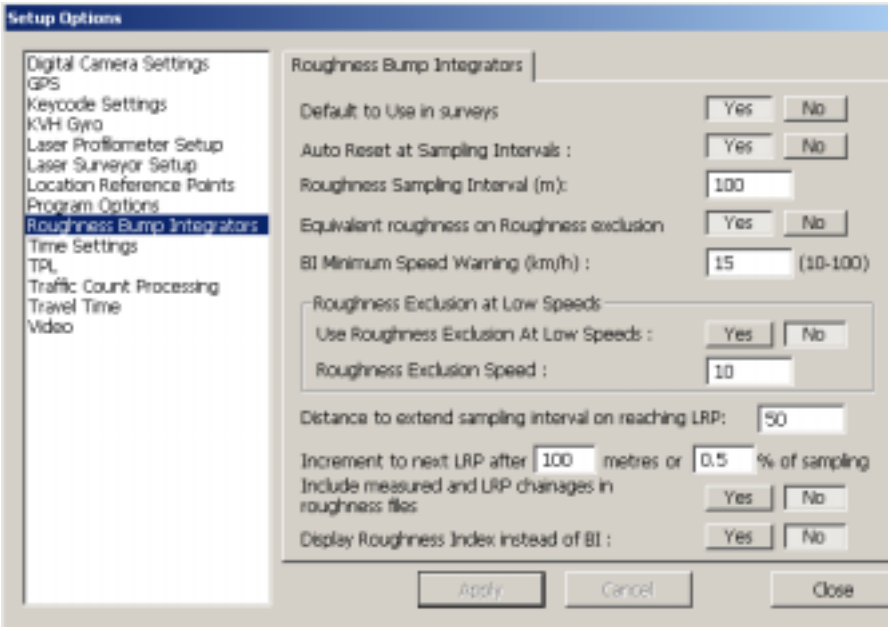
- Visual keyboard rating;
- Location reference points;
- Transverse profile and rut depth;
- GPS measurements;
- Moving traffic survey;
- Skid resistance.

Resolution of BI Measurements

The accuracy of the roughness measurements is a function of the precision of the bump integrator (BI). The ROMDAS BI encoder returns 360 pulses per revolution. With a spindle diameter of 45 mm this corresponds to approximately 2.5 pulses per mm of vertical travel, or a resolution of approximately 0.4 mm.

9.2 Roughness Survey Setup Options

Roughness Survey Setup Options



- **Auto Reset at Sampling Intervals**: Normally, one defines a sampling

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interval for roughness surveys which is a fixed length (e.g. 100 m). ROMDAS then automatically resets the roughness counts at the end of this sampling interval. However, if you wish to manually reset the roughness at the end of a sampling interval you would enter "N" here. The resets would then be done by pressing the ESC key. In practice, this is only done with long sampling intervals, such as 1000 m, and is not normally recommended.

- **Default Sampling Interval (m)**: The roughness sampling interval is the regular interval over which to sum the roughness counts. It is recommended that 100 m be used for the minimum sampling interval. Even if data are only required at longer intervals, for example 1000 m, by sampling at short intervals the data can be aggregated upwards. However, if a large sampling interval is used the data cannot be disaggregated downwards. It is not recommended that intervals less than 50 m be used since, particularly on roads with low roughnesses, they can give misleading results.
- **BI Minimum Speed Warning**. This is the minimum survey speed. If the average speed in the roughness survey over an interval drops below the minimum speed, the computer will beep at the end of the interval.

9.3 Executing the Survey

Defining Survey Data

When the **Surveys** option is selected, the standard survey input screen shown below is displayed. The data entered are as follows:

- **Survey ID**: A unique code identifying the survey.
- **Survey File**: The name of the file where the data are stored. This defaults to the Survey ID.
- **Description**: A description of the survey.
- **LRP Reset**: How LRPs are used in the survey (No/Yes/Define).
- **LRP Data Files**: The name of the data file with the LRPs (if 'Yes' selected for LRP reset).
- **Start** [P15]**Chainage**: The chainage along the road where the survey is starting. This will usually be 0. It would be non-zero if the survey starting part way along the road.
- **Direction**: This indicates if the measurements are increasing or decreasing. For example, a road section starting at 0 and going to 1000 m is increasing, with the other direction being classified as decreasing.
- **Operator:** The name of the operator for the survey.
- **Vehicle:** The vehicle used in the survey. The data are selected for a list based on the vehicle calibrations.

An important entry is the **Roughness Interval**. This is the distance (in m) that the roughness measurements will be summarised over. Typically 100 m is used.

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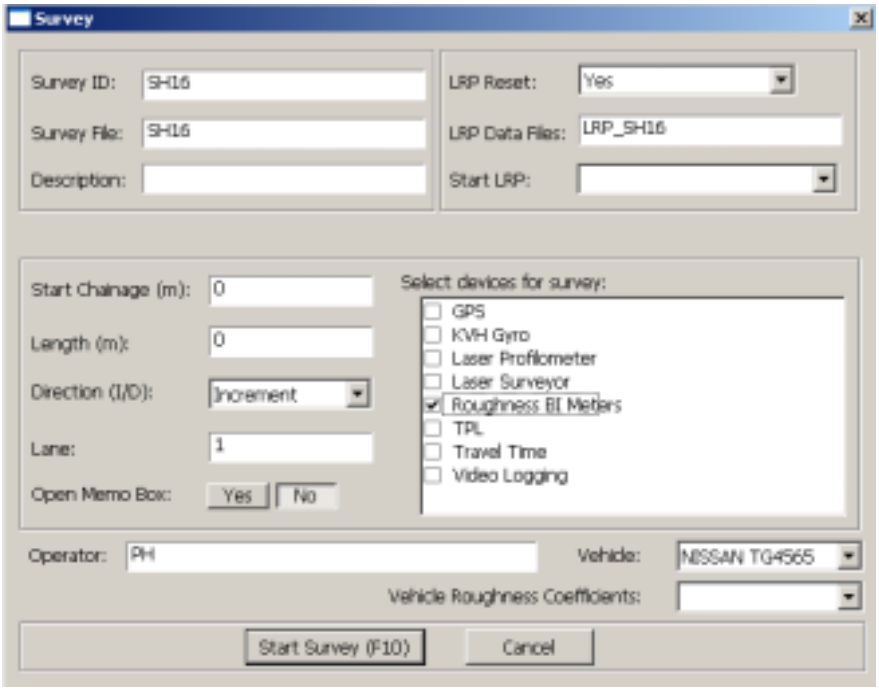
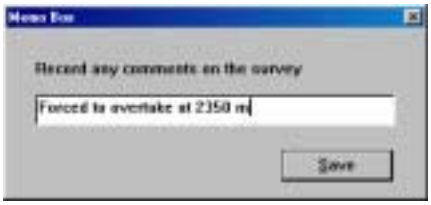


There are a number of optional settings which allow for additional instruments to be used in the survey (TPL, video logging, GPS, GripTester). For these to be used it is necessary to enable them as described under setting up the system (see Chapter 16).

The **Open Memo Box** option allows user to enter comments on the survey when the survey ends. This data is stored with the survey logs. At the completion of the survey a memo box will be opened This option is controlled under **Setup|Options|Program Settings**.



Starting the Survey

Once all the survey data are entered select F10. Press the **Space Bar** to start surveying.

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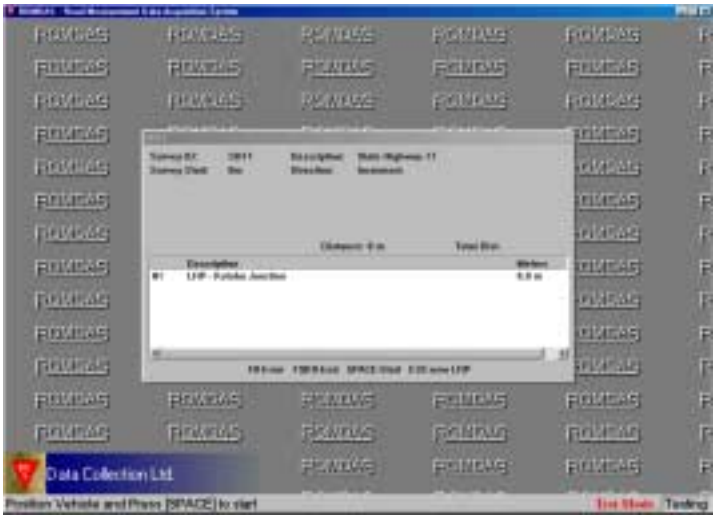
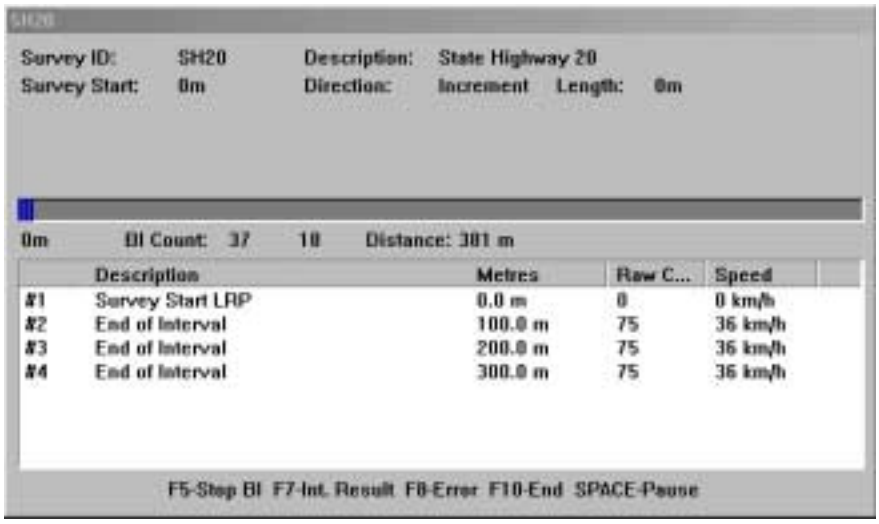


During the Survey

During the survey the roughness will be displayed from each bump integrator, along with the distance travelled. At the end of each roughness interval the total raw BI count and the average speed is displayed. In the example below there were 75 counts/100 m and an average speed of 36 km/h.


Survey ID: SH20 Description: State Highway 20
Survey Start: 0m Direction: Increment Length: 0m
0m BI Count: 37 18 Distance: 381 m
Description Metres Raw C... Speed
#1 Survey Start LRP 0.0 m 0 0 km/h
#2 End of Interval 100.0 m 75 36 km/h
#3 End of Interval 200.0 m 75 36 km/h
#4 End of Interval 300.0 m 75 36 km/h
F5-Stop BI F7-Int. Result F8-Error F10-End SPACE-Pause

If keyboard rating is performed during the survey this will be displayed. Below is an example of recording a bridge.

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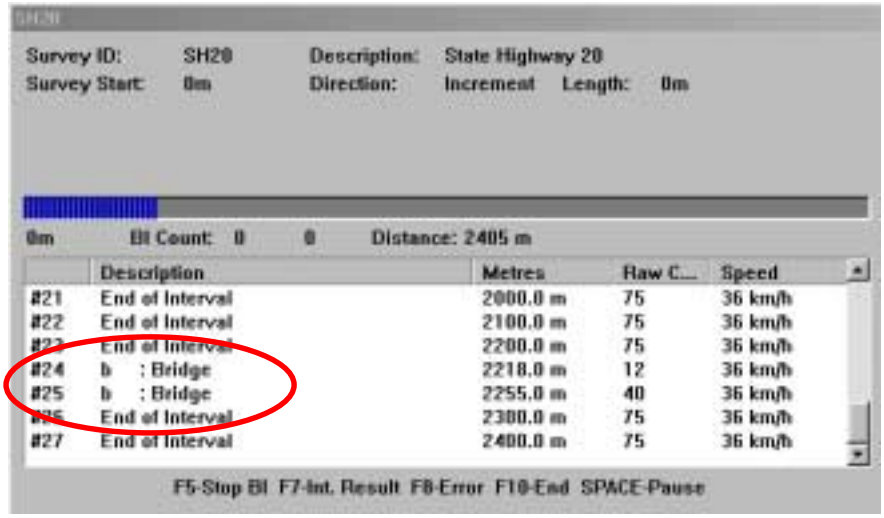
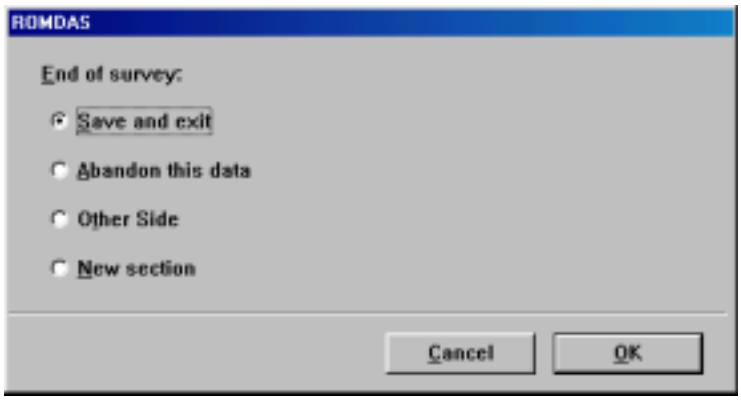

Survey ID: SH20 Description: State Highway 20
Survey Start: 0m Direction: Increment Length: 0m
0m Bl Count: 0 0 Distance: 2405 m
Description Metres Raw C... Speed
#21 End of Interval 2000.0 m 75 36 km/h
#22 End of Interval 2100.0 m 75 36 km/h
#24 b : Bridge 2218.0 m 12 36 km/h
#25 b : Bridge 2255.0 m 40 36 km/h
#27 End of Interval 2400.0 m 75 36 km/h
F5-Stop Bl F7-Int. Result F8-Error F10-End SPACE-Pause

Ending the Survey

At the completion of the survey press the **F10** key. The screen below will be shown.



The **Other Side** option enables for the road to be surveyed in the opposite direction (see Section 4.5). **New Section** allows for another section to be surveyed immediately.

Example of Data

An example of the key data from the survey is shown below. A full description of the data is given in Chapter 16.

Continuing Previous Surveys

The **continue previous surveys** works in the same manner as described in Section 7.2 for keyboard rating surveys.

9.4 Pausing Roughness Recording

Overview

During surveys there are often times when it is desirable to pause the roughness recording (roughness exclusion), for example:

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- If there are road works
- On bridges
- Over fords
- At low speeds (below the BI calibration speeds)

This can be done in three different ways

- manually by pressing the **F5** key
- by associating a keyboard continuous or switch event with pausing the roughness measurements.
- By setting the **Roughness Exclusion at low speeds** parameters (see Section 9.2)

Roughness Options

There are two options for storing the roughness data when a survey is paused:

- **Actual Roughness Count:** This is the actual roughness recorded over the sampling interval when the measurements were not paused; or,
- **Equivalent Roughness Count:** This is the roughness over the interval based on the measurements that were actually made.

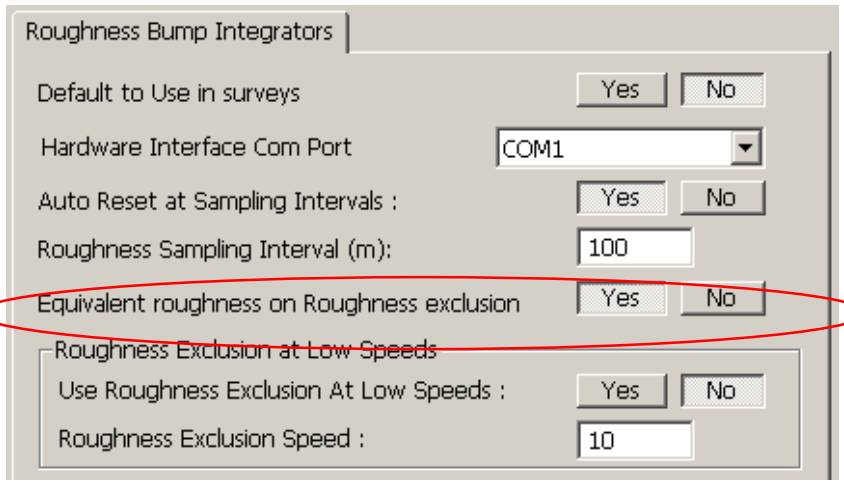
The equivalent is calculated as follows:

$$ECOUNT = COUNT * SAMPLEIN / MEASURED$$

where	ECOUNT	is the equivalent roughness count in counts/sample interval
	SAMPLEIN	is the sampling interval in m (usually 100 m)
	MEASURED	is the length of the sampling interval roughnesses were measured over in m

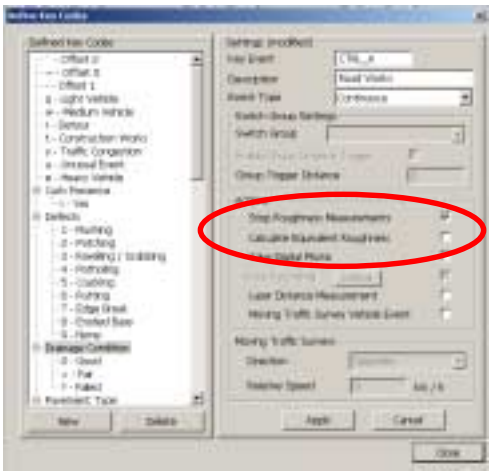
For example, if you measured for 70 m out of a 100 m interval and there were 10 counts, the equivalent roughness would be 14.

The default setting is for **Equivalent Roughness on Roughness exclusion** to be set to Yes



Setting Up Keyboard Events

To associate pausing the roughness measurements with a keyboard continuous or switch event the settings are activated as shown to the right. Multiple events can be defined, each with their own setting.



Defining keyboard events is described in Section 6.3.

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10 Video Surveys

10.1 Introduction

Overview

The ROMDAS video recording system allows a camera to be used during a ROMDAS survey to record images from the moving vehicle. The most common application is to mount the camera facing forwards to record the right-of-way, although it is also possible to record sideways or to the rear of the vehicle. Multiple cameras can be used simultaneously.

The data is digitised directly to the computer. In real time key data are overlaid on the image including the road chainage, date, time, GPS co-ordinates, roughness, and more. The user has a high degree of control over what is displayed.

Direct Digitising

Direct digitising is accomplished through a IEEE Firewire connection in the computer.

When digitising it is common to sample images at intervals of 5 – 10 m. This is more than adequate for road surveys and ensures that the file size is manageable[10].

10.2 Video Survey Setup Options

Overview

In order for the ROMDAS Video Logging to work you will need to ensure that the following are installed and working correctly:

- DirectX version 9.0 or greater
- Pegasus MJPEG Compressor/Decompressor
- The IEEE 1394 Firewire connection
- The drivers for the Video device

This section describes the installation of these components.

DirectX Installation

DirectX is used by ROMDAS for its graphical overlay.
To confirm that the version of DirectX on you ROMDAS computer is version 9.0 or greater run the DirectX Diagnostic Tool dxdiag.exe. This is run by selecting **Windows Start|Run** and typing **dxdiag** into the box (see

[10] The camera output is 30 frames/s (PAL) or 25 frames/s (NTSC). At typical survey speeds this corresponds to less than 1 m between images. At 0.2 MB/image this can quickly lead to large files.

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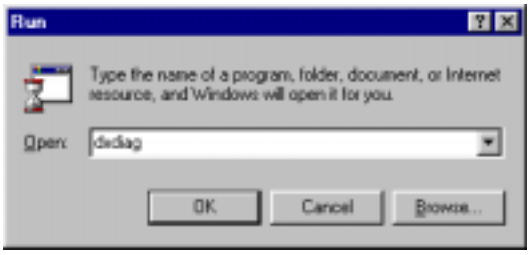
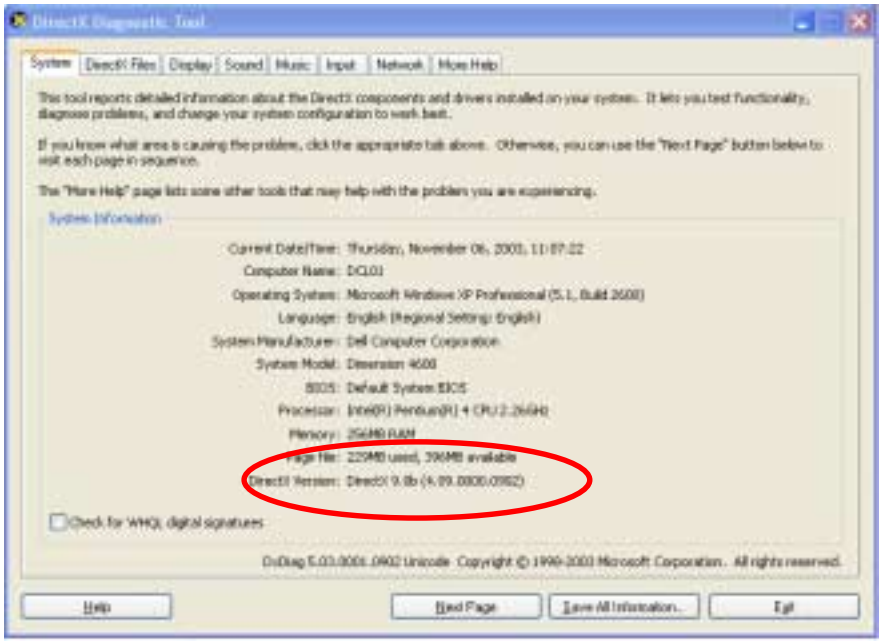
below).



Confirm the version under the System information .



If the version of DirectX is not v 9.0 or higher, it will be necessary to install DirectX from the ROMDAS CD. This is done by highlighting the menu entry:

Software Extras|Video Logging|DirectX

Once installed, the status should be tested by running dxdiag and using the **Display** tab. As shown to the right, this will test all functions and confirm that DirectX is working correctly.

Pegasus Compression

We recommend the Pegasus Motion JPEG (MJPEG) compressor/ decompressor for ROMDAS direct digitising. Any other Video Codec's can be used if desired. The Pegasus codec is installed with ROMDAS but

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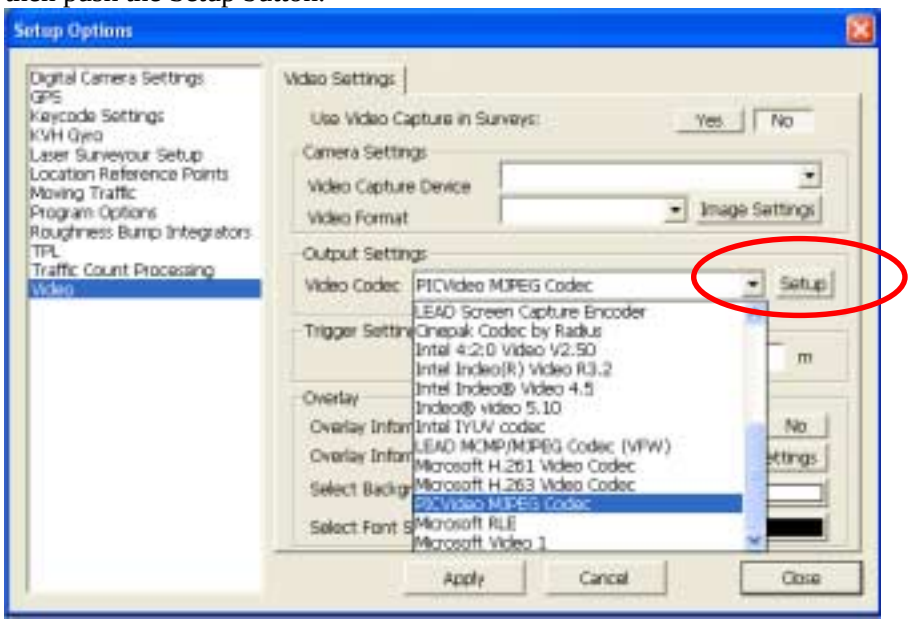
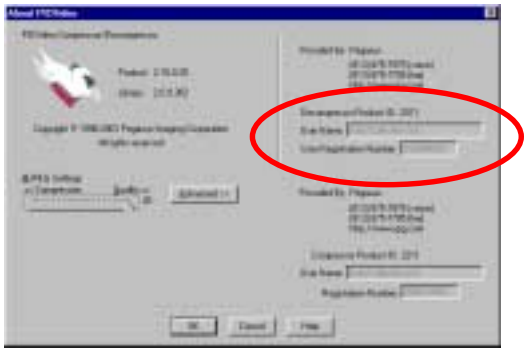
it is necessary to test that the installation was successful.

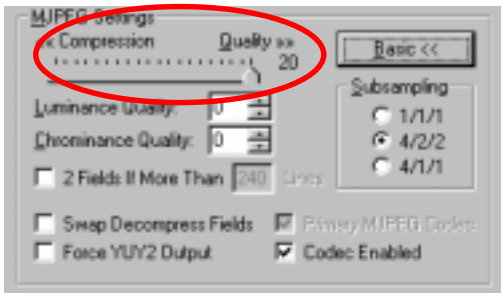
Select the PIC Video MPEG Codec from the available Video Codec's and then push the Setup button.



You should have PICVideo MJPEG Codec installed. Highlight an select Properties|Settings and see if the User Name and Registration numbers are entered correctly. If they are not correct, please contact info@romdas.com for support.



Select the **Advanced** button and the screen MJPEG Settings will change to that to the right. This allows for the quality of the image to be adjusted. Some settings will need to be checked/adjusted:



- The **Compression** setting is the most important as this dictates the quality and size of the image. If sampling at 5-10 m a value of **18** should generally be used since this gives a good balance between files size and image quality.
- The **Luminance** and **Chrominance Quality** settings can be adjusted to get the optimum display on the camera.

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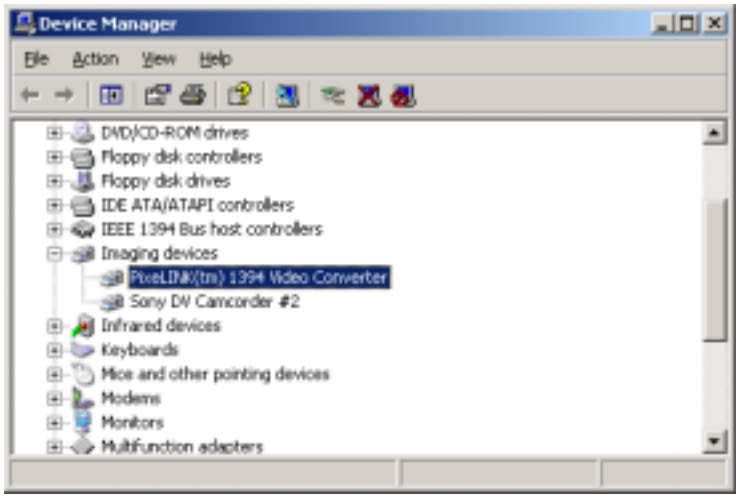
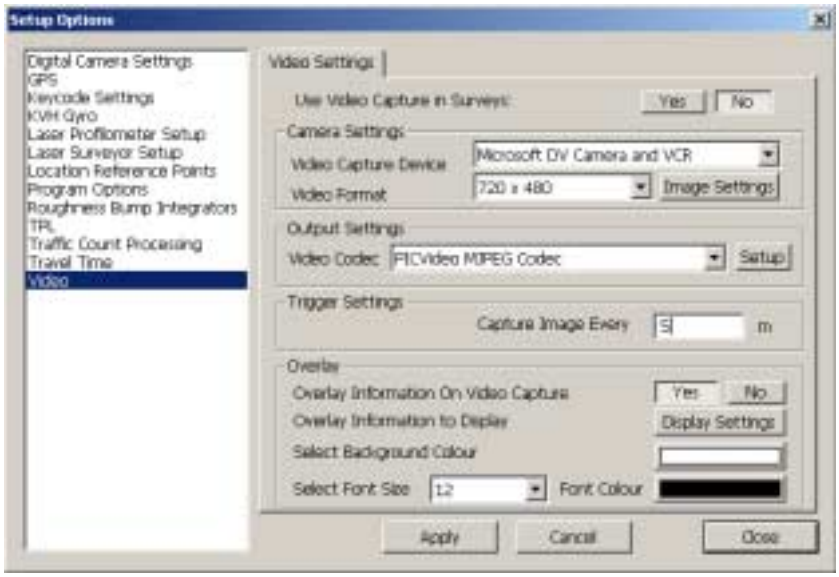
Firewire Connection

The final test is whether the Firewire connection has been made. Install the Firewire device following the instructions in Appendix E. With the camera or Analog to Firewire converter plugged in you should be able to see it in the Windows device manager under Imaging Devices such as shown below.



Video Survey Setup Options

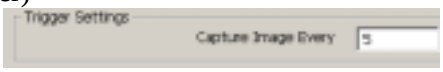
The video software options are defined under **Setup|Options|Video**. This option will only be active if you have purchased the video option (unless you are using the evaluation software which has all options available for 30 days). When selected, the form below will be shown.



- **Video Capture Device**: The drop down box will display all the Imaging Devices that Windows detects are currently connected to the system.
- **Video Format:** Most imaging devices will give a choice of Video

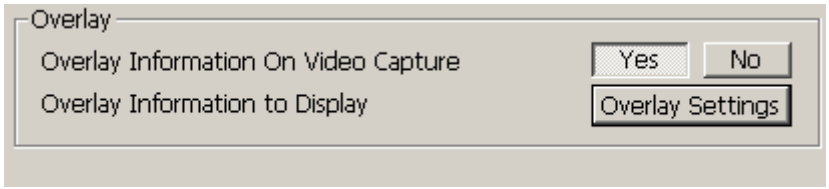
resolution which can be selected here. A higher resolution will increase the file size.

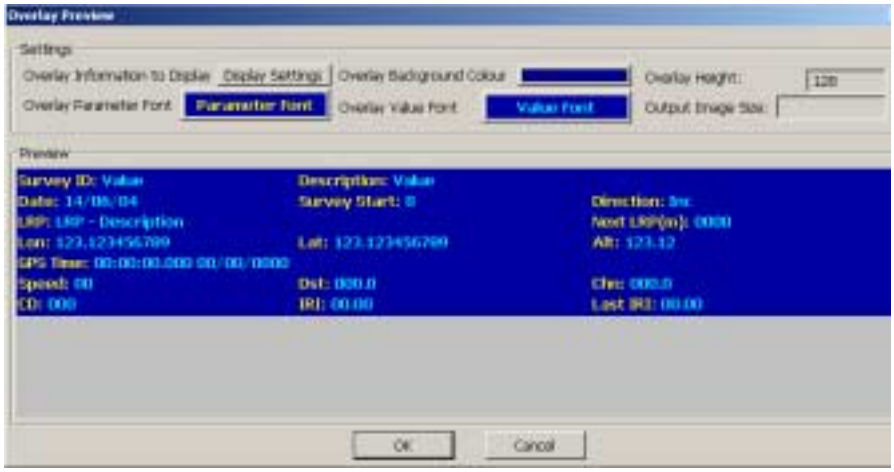
- **Video Codec**: The drop down box will display all the Compression Codec's that are installed. We recommend the Pegasus MPEG compression codec that is installed with ROMDAS (see Pegasus Compression section in this chapter)
- **Capture Image Every**: The interval (in m) when frame captures are to be recorded is defined.



Overlay

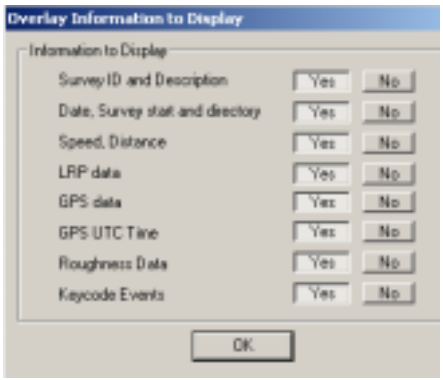
The overlay settings box controls the appearance of the overlay.





The **Overlay Background Colour** setting controls the colour of the overlay background while the font type, size and colours can be changed in the Parameter Font and Value Font options. These should be selected for the best contrast.

Selecting the **Display Settings** opens the screen to the right. This enables the user to select which information to display on the overlay. Contact DCL if you have special customisation needs.



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10.3 Hardware Settings

Camera Settings

The key to successful video surveys is to ensure that the zoom and focus to the camera are centred on the features of interest. One should decide on the object of interest and set the system up accordingly. For a right-of-way video one would have a much wider zoom with the camera focused at a distance from the vehicle whereas for recording pavements one would zoom the camera at a spot immediately in front of the vehicle.

It is also important to ensure that the heading image is centred in the frame.

10.4 Executing Video Surveys

Overview

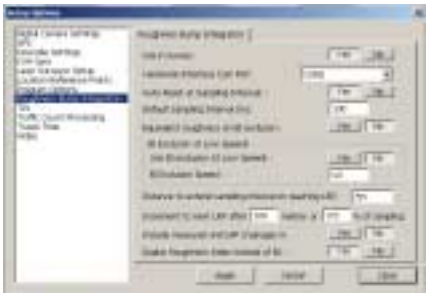
There are some specific issues which need to be considered with video surveys, above the normal survey requirements.

Roughness Display

When using roughness with the video survey there are two options to display the roughness values on the video overlay:

- **Raw Roughness**: The total raw BI count/km is displayed (default); or,
- **Roughness Index**: This is an approximation of the calibrated roughness over the preceding interval length.

When the **Display Roughness Index Instead of BI** is selected the roughness calibration coefficients of the vehicle used in the survey are used to calculate the roughness index over the previous interval length.



10.5 Processing Digitising Videos

Digitising Options

Under **Data Processing** the **Export Raw** option produces a table where each video frame is correlated to the road chainage it was triggered at.

GEO – 3D Output

The Process GEO – 3D output file will produce a dbf file in the format required by the Trident GEO-3D software which correlates frames with road chainage and GPS data.

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11 GPS Surveys

11.1 Introduction

Overview

GPS surveys are done to obtain the spatial co-ordinates (*ie* the latitude and longitude) of the road elements. The data falls into two groups:

- **Road Centreline.** The centreline is a nominal line which represents the road alignment.
- **Events.** Data identified through keyboard events.

To conduct a GPS survey it is necessary to have a GPS receiver. ROMDAS will work with any receiver with NMEA output but is specifically designed to work with Trimble receivers. When Trimble receivers are used the data can be post-processed to differentially correct the data for enhanced accuracy.

GPS surveys can be conducted on their own, or in conjunction with roughness, rut depth, travel time, or any other type of survey.

This chapter opens with a discussion of the principles of GPS measurement and how GPS surveys should be planned. A proper understanding of these two issues is essential for accurate data collection. This is then followed by how the GPS data are analysed and exported to other systems.

The report 'Using ROMDAS for Network Referencing and Mapping Surveys' describes the procedure for GPS surveys and data processing in detail. This is available on the ROMDAS CD or from www.ROMDAS.com.

11.2 Principles of GPS Measurements

Overview

The Navigation Satellite Timing and Ranging (NAVSTAR) GPS is a space-based satellite radio navigation system developed by the U.S. Department of Defence. There are a series of 24 satellites placed in 6 orbital planes about 20,200 km above the earth's surface. The satellites are in circular orbits with a 12-hour orbital period and inclination angle of 55 degrees. This orientation normally provides a GPS user with a minimum of five satellites in view from any point on Earth at any one time.

Each satellite continuously broadcasts a radio frequency signal. To determine a range, the GPS receiver measures the time required for the GPS signal to travel from the satellite to the receiver antenna. The timing code generated by each satellite is compared to an identical code generated by the receiver. The receiver's code is shifted until it matches

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the satellite's code. The resulting time shift is multiplied by the speed of light to arrive at the apparent range measurement.

Since the resulting range measurement contains propagation delays due to atmospheric effects, and satellite and receiver clock errors, it is referred to as a "pseudorange". Changes in each of these pseudoranges over a short period of time are also measured and processed by the receiver. These measurements, referred to as "delta-pseudoranges" are used to compute velocity.

A minimum of four pseudorange measurements are required by the receiver to mathematically determine time and the three components of position (latitude, longitude, and altitude). Figure 11.1 shows how three satellites are used to establish position. This figure does not include the fourth timing satellite.

After the four range equations are solved, the receiver has estimates of its position and time. Similar equations are then used to calculate velocity using the relative velocities instead of pseudoranges. The position, velocity and time data are generally computed once per second.

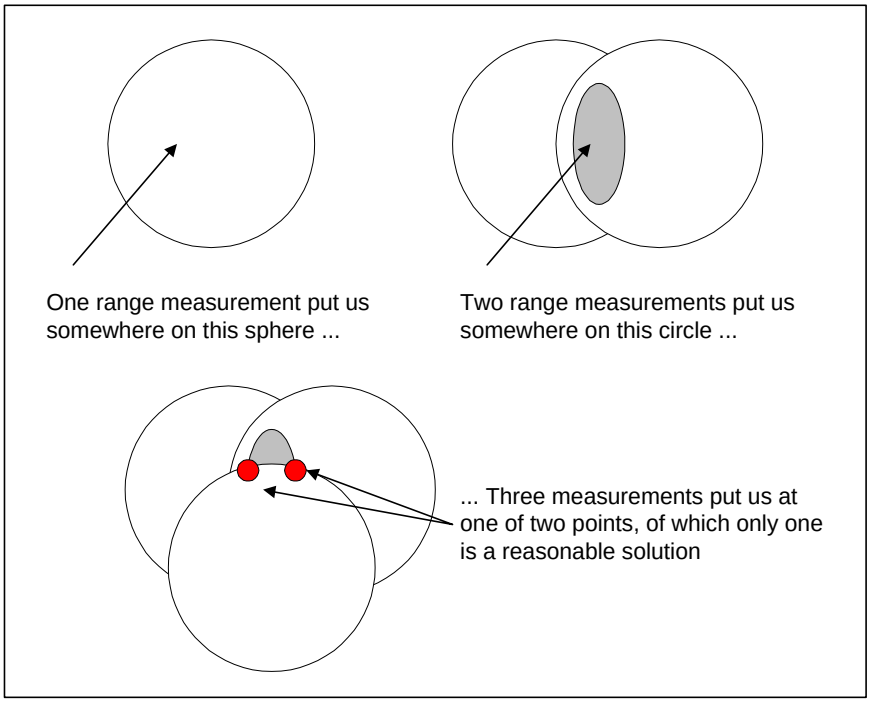
One range measurement put us somewhere on this sphere ...
Two range measurements put us somewhere on this circle ...
... Three measurements put us at one of two points, of which only one is a reasonable solution

Figure 11.1: Satellite Triangulation

UTC and GPS Time

There are two time measures used with GPS measurements:

- **UTC Time:** The 'Coordinated Universal Time (UTC)' is the time scale based on the atomic clocks used in the GPS satellites. This is occasionally corrected by the insertion of leap seconds[11], so as to keep it approximately synchronised with the earth's motion.
- **GPS Time:** The time scale to which GPS signals are referenced.

[11] See http://maia.usno.navy.mil/eo/leapsec.html for a discussion of the basis for leap seconds.

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GPS time equalled UTC time in 1980, however, due to the leap second adjustments by 2002 the difference between GPS and UTC was 13 seconds (http://maia.usno.navy.mil). This value is used by ROMDAS in post-processing GPS data.

Accuracy of Measurements

The accuracy of GPS measurements depends upon a variety of factors but the two main ones are:

- **Quality of Receiver**. Receivers can be placed into two general categories: consumer grade and survey grade. Consumer grade receivers are low cost and relatively low accuracy. Survey grade receivers cost much more but will give greatly improved results.
- **Differential Correction** This uses data from a base station, whose position is accurately known, to correct for the errors that arise in the field measurements.

As a general rule, it is better to use a low-cost receiver with differential correction than a high cost receiver without. The best results will be obtained using survey grade receivers which are differentially corrected.

Figure 11.2 illustrates the results of differentially correcting data from a low-cost Trimble Pocket Pathfinder GPS receiver. When compared to the actual position the RMS error with the uncorrected data was in the range of 1.23 – 6.32 m, which compared to a range of 1.05 – 1.58 m for the differentially corrected data[12].

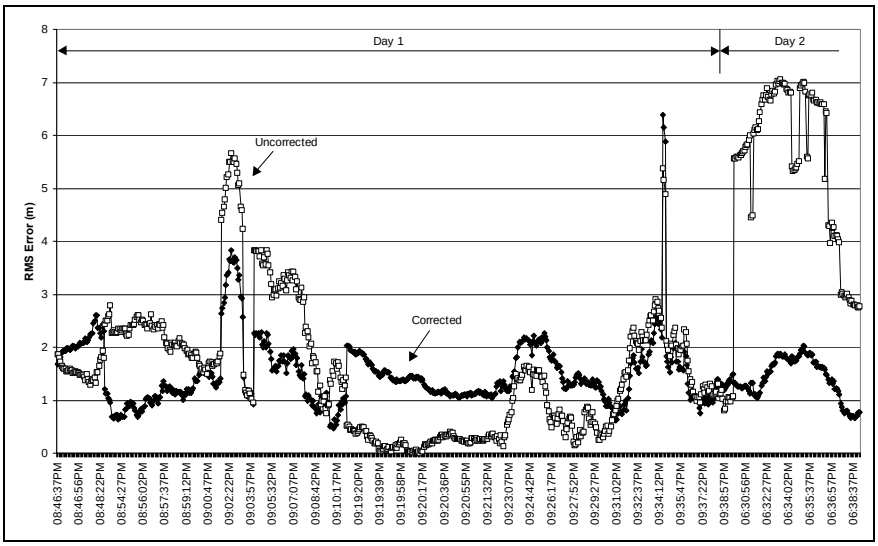

Figure 11.2: Uncorrected vs. Differentially Corrected Data

Figure 11.3 is an example of the high quality results that can be obtained from a differentially corrected survey grade instrument. This figure shows the road centreline recorded with ROMDAS from Apia Samoa along with an aerial photograph for the backdrop.

[12] Additional details on this analysis is available from the ROMDAS CD under the entry: **Reports|GPS Meassurements|Evaluation of Trimble Pocket Pathfinder Accuracy**

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Figure 11.3: ROMDAS GPS Data From Apia Samoa

When to Differentially Correct Data

The question which is often asked is 'are differential corrections always necessary'? The answer is no. Adequate results can be obtained without differential corrections so the benefits of the improved accuracy need to be weighed against the additional costs and complexity that differential corrections entail.

Until 2000 there was a random error in the GPS measurements, called 'Selective Availability' which meant that the 95% confidence interval for the data was +/- 100 m. However, since selective availability has been disabled the 95% confidence intervals are now on the order of +/- 8 – 10 m. For many applications this is sufficient accuracy, although it must be recognised that 5% of the readings could be significantly worse than 10 m.

As a general rule differential corrections should be done under the following conditions:

- If base station data are readily available, for example there are often commercial suppliers of the data or it is practical to set up your own base station.
- If you will never be more than 300 km from the base station, since the accuracy decreases with increasing distance.
- If the survey requirements call for accuracies of better than 5 m.

Differential corrections are straightforward with ROMDAS. They can be done using two different methods:

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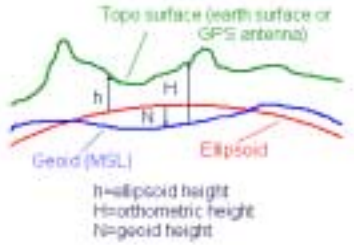
- **Base Station**. The software is designed to store Trimble GPS receiver data so that it can be differentially corrected with data from a base station using Trimble Pathfinder Office. The results are stored to a .SSF file.
- **Real-Time Corrections.** Suppliers such as Omnistar transmit real-time differential corrections for many countries. These data can be logged during the surveys so there is no post-processing.

GPS Altitude

The GPS altitude can be measured in two ways:

- Height Above Ellipsoid (HAE)
- Height Above Mean Sea Level (MSL)

As shown to the right, the MSL is a **geoid** which is an imaginary surface determined by the earth's gravity. An **ellipsoid** is a reference which approximates the earth's surface.



ROMDAS stores the altitude in terms of HAE. This is recorded directly for Trimble receivers, and for NMEA receivers calculated from the GGA string data[13]. ROMDAS FOR DOS only used MSL.

11.3 Inertial Corrections for GPS Satellite Loss

Overview

Since GPS receivers rely on satellites, it is common to lose the satellite signal at some stage during a survey, particularly in urban areas where high buildings have a 'canyon' effect. To overcome this effect, a gyroscope (called an 'inertial navigation system' or INS) can be used with ROMDAS. The output from the gyroscope is used to estimate the GPS co-ordinates during time of satellite signal loss.

ROMDAS Gyroscope

ROMDAS uses a fibre-optic gyroscope (FOG) for its inertial navigation.

FOG gyroscopes are based on the principle of a laser passing light through a looped fibre optic cable in clockwise and counter-clockwise directions. Inertial rotation of the unit will result in a change of path lengths, and thus, an effective relative phase change at a detector.

[13] The NMEA GGA string contains the MSL data (field 9) and the height of MSL relative to the WGS84 ellipsoid (field 11). The sum of these two is the HAE.

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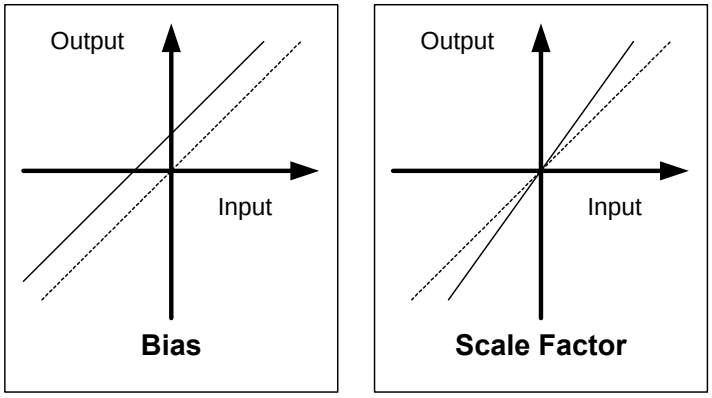
The gyroscope measures the relative change from the previous position. The output from the ROMDAS gyroscope is degrees/s.

Measurement Errors

As described in Grewal, *et al.* (2001)[14] the following measurement errors may be present in any gyroscope system:

- Bias, which is any non-zero sensor output when the input is zero;
- Scale Factor Error, often resulting from aging or manufacturing tolerance;
- Nonlinearity, which is present in most sensors to some degree;
- Scale Factor Sign Asymmetry, often from mismatched push-pull amplifiers
- Dead Zone, where the gyroscope does not respond to inputs
- Quantisation Error, where there is a discontinuous output, inherent in all digitised systems.

With the ROMDAS gyroscope the two relevant errors are bias and scale factor, and their effects are illustrated in the two figures below. If these errors were not present the solid line (representing the gyroscope output) would be on the diagonal.



Error Corrections

When any gyroscope is stationary there will be a bias drift which is a function of temperature. At a fixed temperature it can be in the range of 2 – 4 degrees/h. This is corrected by using the ROMDAS gyroscope calibration procedure described in Section 5.6.

With the gyroscope stationary, an autobias test is run., This monitors the output of the gyroscope and calculates an appropriate bias correction factor. Since for FOG gyroscopes the bias is affected by temperature, it is recommended that the factor be recorded at a range of temperatures and a bias/temperature relationship be developed. This is then input to the ROMDAS software.

They gyroscope scale factor linearity at a constant temperature is less than 0.5%, and less than 1% over the full range of temperatures. The least

[14] Grewal, M.S., Weill, L.R., and Andrews, A.P. (2001). *Global Position Systems, Inertial Navigation and Integration.* John Wiley & Sons, New York.

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significant angle bit is 0.000305 degrees and this represents the scale factor correction in ROMDAS.

11.4 Survey Planning

Objective

Since GPS satellites orbit the Earth on six different orbital paths, during the course of every day the number of satellites overhead changes as the satellites move. This affects the accuracy of the GPS measurements (as represented by the PDOP) and so it is necessary to plan GPS surveys to ensure that they are timed to avoid periods of poor PDOP.

GPS mission planning is an easy and accurate way for GPS users to determine the number of satellites available and the quality of their arrangement over any period of time.
To perform mission planning you first need a current emphemeris file. This contains accurate information about which satellites are available and where they will be at any given time.
With a current ephemeris file mission planning software such as Quickplan from Trimble Navigation Ltd can be used to generate charts showing the number of satellites available and the quality of their arrangement over any selected period of time. This enables the user to plan their GPS work to coincide with the optimal satellite conditions.

Trimble Quickplan Mission Planning Software
ftp://ftp.trimble.com/pub/survey/gpsurvey/qkp235.exe

Current Almanac File
ftp://ftp.trimble.com/pub/eph/current.ssf

Trimble Quickplan Software

The Trimble Quickplan ® software is a publicly available package which is specifically designed to assist with survey planning. It is used with a current ephemeris almanac file which contains accurate information about which satellites are available and where they will be at any given time. Charts can be generated showing the number of satellites available and the quality of their arrangement over any selected period of time. This enables the user to plan their GPS work to coincide with the optimal satellite conditions.

The software and the almanac file can be obtained from the Internet at:

Trimble Quickplan Mission Planning Software

ftp://ftp.trimble.com/pub/survey/gpsurvey/qkp235.exe

Current Almanac File

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ftp://ftp.trimble.com/pub/eph/current.ssf

The software and a sample almanac are also included on the ROMDAS CD. The software can be installed from the menu setting:

Additional Software|GPS|Trimble Quickplan GPS Survey Planning

During installation a prompt is given for the type of almanac file to be used in the planning (see right). Select the **SSF** option since the almanac will be downloaded from the Trimble web site.

Once the software is installed, there are two steps required:

- **Basic Setup**. This sees the basic parameters established for use with the software.
- **Daily Planning**. This uses the current almanac file to assess the daily satellite geometry and times when surveys should or should not run.

Basic Quickplan Setup

The first step is to obtain the current almanac file using the link given earlier. Save this file in a folder on your hard disk.

When the Quickplan software is started, the display to the right is given. This is used to define when the survey is to be conducted. For the initial setup, select **Today** and then **OK**.

The location of the survey must then be defined using the screen presented to the right. There are three options for selecting the location:

- **Map**. A map of the world is presented from which it is possible to select the location. Having clicked on a location one can then use the **Magnify** button to zoom in (see middle right). Once the location is found select **OK**.
- **Cities**. A list of cities is given. The default setting is for the USA but selecting **World** gives

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a list of world cities.

- **Keyboard**. The latitude and longitude of the position can be defined (see lower right).

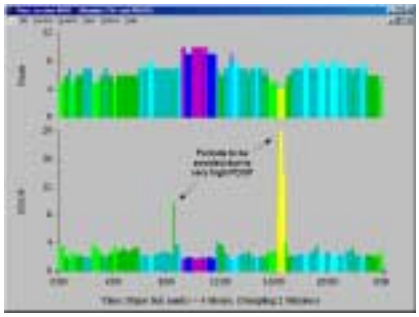
Once the position is defined, select:

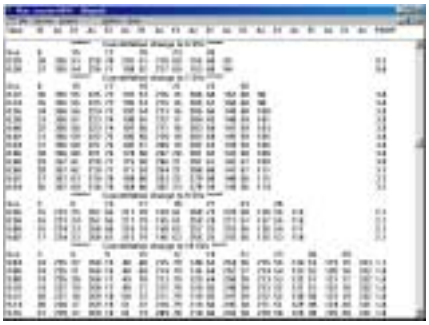
Options|Almanac

Select the almanac file saved earlier. The mission planning can now be conducted.

Daily Survey Planning

Once the Quickplan software is installed and a current almanac file is selected, it is possible to evaluate the number of satellites and PDOP by time of day using the **Graph** command. This lists the various types of graphs that can be plotted. As shown below (left), it clearly shows the time of day when surveys should not be conducted. In the example below, the best times for surveys are 9:00 – 11:30 and 12:30 – 15:30. They should be avoided around 16:00-16:30. The actual PDOP values can be viewed by selecting **Options|Show Report** (below, right).





11.5 GPS Setup Options

GPS Settings

The GPS options are defined under **Setup|Options|GPS**. This option will only be active if you have purchased the GPS option (unless you are using the evaluation software which has all options available for 30 days). When selected, the form below will be shown.

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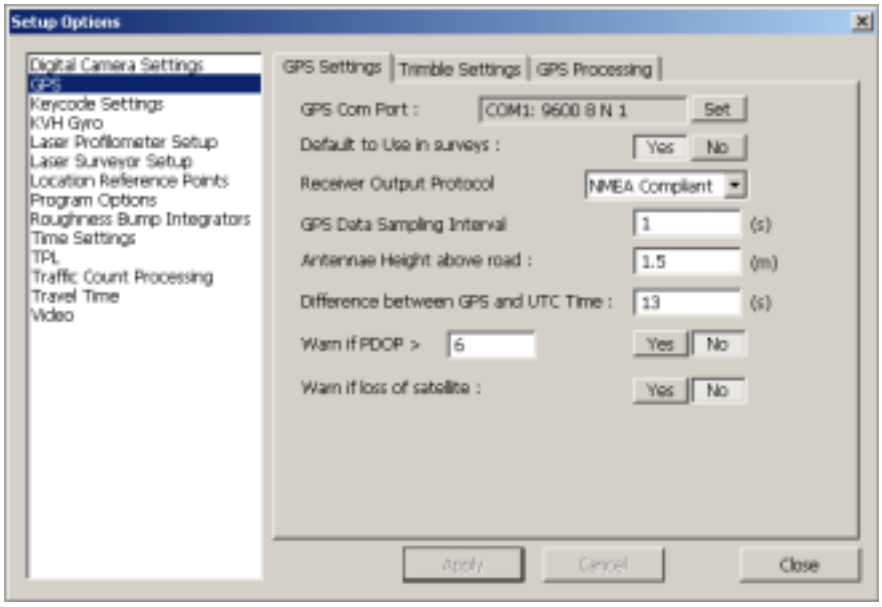

- **Default to Use in Survey.** This entry must be set to **Yes** in order to store the GPS data.
- **GPS Data Sampling Interval.** This is how frequent ROMDAS samples the GPS data. Usually set to 1 second. This is limited by the output rate of the receiver.
- **Receiver Output Protocol.** This is the type of GPS receiver.
  - **Trimble TSIP**. Used for Trimble GPS receivers set to output in the TSIP mode (Trimble Standard Interface Protocol).
  - **NMEA Compliant**. Used for receivers capable of outputting in the NMEA 0183 2.0 protocol.
- **Antenna Height Above Road**. This is the height of the GPS antenna above the road surface. It is deducted from the GPS altitude to get the altitude of the road surface.
- **Difference Between GPS and UTC Time**. There is a difference between the GPS time and the true UTC time (see Section 11.2 or http://maia.usno.navy.mil/). When post-processing the data with Trimble pathfinder office this needs to be corrected. The default value entered here should not be altered without reference to the above web site.
- **Warn if PDOP**. This will issue a warning to the ROMDAS operator if the PDOP is greater than a certain value.
- **Warn if Loss of Satellite**. This warns the operator when there is a loss of satellite.

Trimble Settings

When using the Trimble TSIP mode there are a number of the receiver settings which can be directly set from ROMDAS **Trimble Settings** menu.

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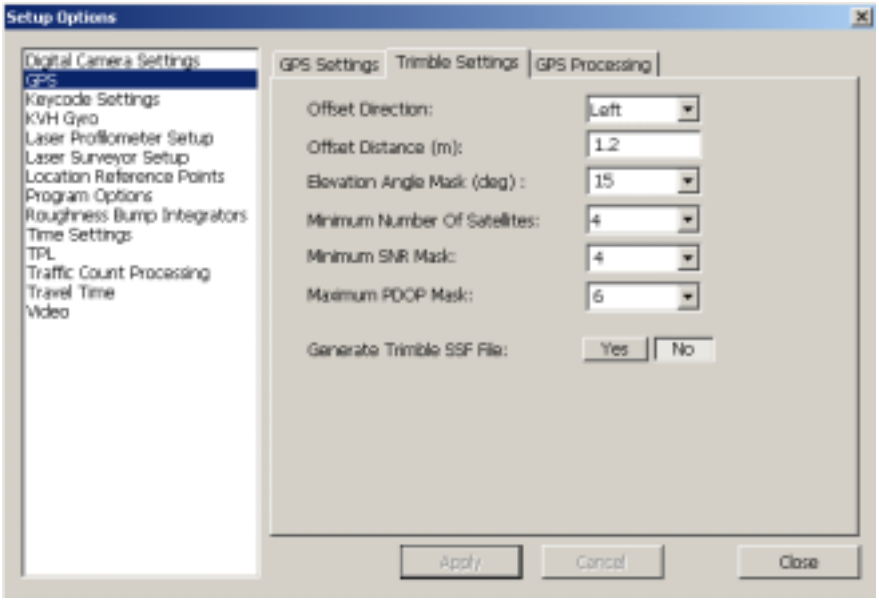

- **Offset Direction**. To record the road centre-line when travelling down the lane the recorded GPS positions need an offset and direction applied. These offset co-ordinates are exported form PathFinder Office into the export Text file and imported back into the ROMDAS Processed GPS table. The Trimble SSF file line feature will have this offset direction (left or right) applied for the Offset Distance below.
- **Offset Direction**. The Trimble SSF file line feature will have this offset distance in (meters) applied in the direction of the Offset Direction parameter.
- **Elevation Angle Mask:** This option is critical if you are wanting to differentially correct your data with a local base station. If it is set too low your reciever may use satillites which are are not visible to, or usable by , the base station, making it impossible to correct the data you have logged. If the elevation mask is set too high, it will unnecessarily reduce satellite availability. If wanting to differentially correct the data it should be set higher the further away you are from the base station.
- **SNR Mask:** Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to the background noise. Accuracy degrades as the signal strength decreases. You can configure the SNR mask on your datalogger to log only GPS positions below a certain SNR value.
- **PDOP Mask:** Position Dilution of Precision (PDOP) is a measure of the satellite geometry. The lower the PDOP value, the more accurate the GPS positions. The PDOP mask is set to esure that only data of the required accuracy is collected. If the PDOP exceeds the configured mask the reciever stops logging positions. The recommended PDOP mask is 6.

  Note: PDOP and SNR act in opposite directions: greater accuracy is achieved with low PDOP and high SNR.

GPS Data Logging

During the survey a file is created which contains the data from the GPS receiver. The file structure and its comments is shown below.

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	Field Name	Data Type	
	CHAINAGE	Number	Chainage (m)
	TIME	Number	Time (s)
	LRP_NUMBER	Number	LRP Number
	GPS_TIME	Text	GPS Time (s)
	UTC_DATE	Text	UTC Date
	LATITUDE	Number	GPS Latitude (decimal degrees)
	LONGITUDE	Number	GPS Longitude (decimal degrees)
	ALTITUDE	Number	GPS Altitude (m)
	HEADING	Number	GPS heading (degrees)
	PDOP	Number	PDOP
	DGPS	Yes/No	Differential GPS

The GPS data are logged against chainage at the rate set in the GPS Sampling frequency setting.

11.6 Differentially Correcting GPS Data

Overview

Unless some form of real-time differential corrections were employed (*eg* Starfire, Omnistar, RTCM), it will be necessary to differentially correct the GPS data through post-processing. This section describes how this is done using the .SSF files stored with Trimble GPS receivers.

This section describes how differential correction base station data were obtained and used to correct the survey data. The data source was GPS Control (www.gpscontrol.com) and so the instructions specifically pertain to them, however, the basic principles will apply to other providers.

The GPS Control home page (below) shows that there are three steps to accessing the data:

- Opening an account
- Setting up Trimble Pathfinder Office (or other post-processing software)
- Getting the base station data and differentially correcting the survey data
- Exporting the corrected data as text files

Each of these are addressed individually.

NOTE: This work was done using Trimble Pathfinder Office v 2.70. The procedure will be different for other versions of Pathfinder Office.

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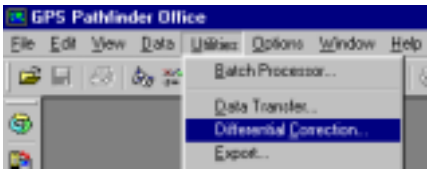
Account

The account option creates an account for the user to access the data and indicates how the data will be paid for.

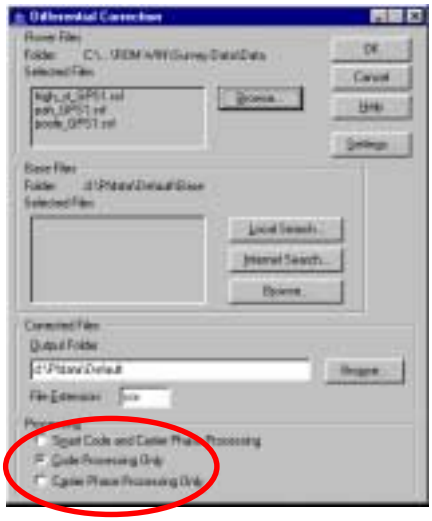
Setting Up Pathfinder Office – Differential Correction Options

It is first necessary to set the basic options for the analysis.

- Select **Utilities|Differential Correction**



The differential correction screen will be shown (see right). This controls where the ROMDAS files (called 'Rover' files) are located, the base station data file location, and the output options.



At the bottom of the form under 'Processing' select **Code Processing Only**.

NOTE: This setting may differ for other base station providers.

Before any of these are defined it is necessary to define the key settings which will be used for the differential corrections. This is done by selecting the **Settings** button and then **Code Processing**.

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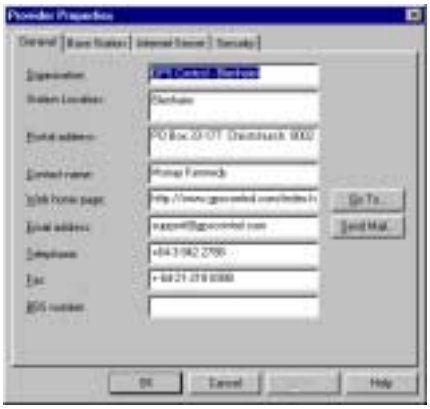
The Code Processing options shown to the right should be selected:

- With Velocity Filtering
- With Filtering and Smoothing

It is necessary to identify the base station provider. This is done by selecting the **Internet Search** button from the differential correction screen. The software will download a list of base station providers from the internet, sorted in terms of increasing distance.

Select the nearest base station site which you have an account for and select **OK**. The 'Provider Properties' screen to the right will be shown giving details of the base station provider.



NOTE: If you are more than 200 km from the base station you will need to set the satellite mask to ensure that you will see the same satellites as the base station.

If it is a commercial provider, such as GPS Control, it is necessary to enter the account name and password to access the data. This is done by selecting the **Security** tab and entering the appropriate data.

Once the data are entered select **OK** and the screen to the right will be shown. The selected base station provider is shown in the drop-down box.

Setting Up Pathfinder Office – Export Options

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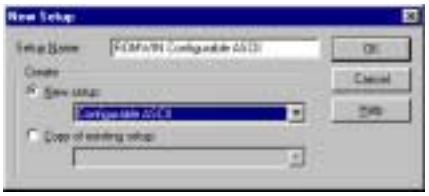
There are two stages to GPS data processing with ROMDAS:

- The ROMDAS survey files are differentially corrected
- The differentially corrected data are exported from Pathfinder Office as text files and then imported into ROMDAS for further analysis. This primarily consists of using the gyroscope to estimate missing GPS positions.

For the second step it is necessary to define the export options in Pathfinder Office. The following describes these settings.

- Select **Utilities|Export**
- Select **New**
- Enter a **Setup Name** (*eg* ROMDAS Configurable ASCII)
- Under the 'New Setup' select **Configurable ASCII**
- Select **OK** to open the 'Properties' window
- Select **Coordinate System**
- Select **Use Export Coordinate System**
- Select **Change**
- Ensure that the co-ordinate system is appropriate. Here the **New Zealand Mapping Grid** has been adopted as the target projection.

  It is possible to use WGS84 Latitutude/Longitude here and to change the projection in MapInfo. However, it has been found that Trimble Pathfinder Office gives more reliable transformations to some projections (*eg* NZMG) than MapInfo.



- Select **Mean Sea Level** for the 'Altitude Measured From'
- Select **OK**
- Select **Configurable ASCII**
- Under 'Files Options' select **All Feature Types in the Same Set of Files**
- Select **New**
- Enter **ROMDAS** as the template name
- Select **OK**
- Ensure that **Line** is selected in the 'Apply To' box
- Define the template settings as

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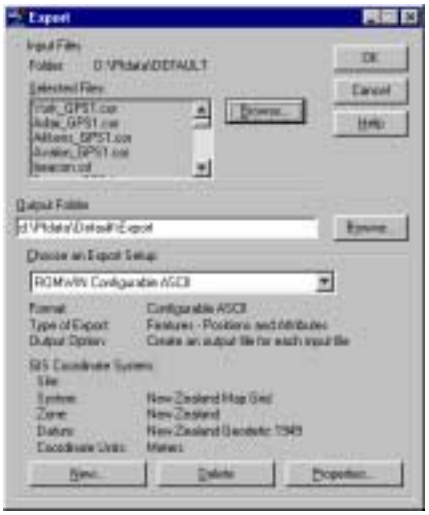
shown to the right. The Latitude, Longitude, Northing, Easting, HAE, MSL and GPS Time data are entered by selecting the individual buttons. They **MUST** be in the order shown to the right for the ROMDAS data processing to operate correctly.

- Select **OK**

Having defined the fields to be exported, it is necessary to confirm the output format.

- Select **Output**
- On the form to the right, select **For each input file create output file(s) of the same name**
- Select **OK**



The final export screen should be as shown to the right below. The important entries are:

- **Output Option**: Creating an output file for each input file
- **GIS Coordinate System**: The correct system (here NZMG).

Processing the Files

With the base station defined the data files can be processed.

- From the 'Differential Correction' menu select **Browse** to locate the rover file folder. The files are normally located under c:\Program Files\ ROMDAS\Survey Data\Data
- Select the files to be processed (see right) and select **Open**
- Select **Internet Search** under 'Base Files'
- Select the appropriate base data provider (see right) and select

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OK

- A screen will be presented asking whether you wish to continue. Select **Yes**
- The files will then be copied from the internet (see right)

NOTE: If the files had already been downloaded the 'Local Search' or 'Browse' button can be used to locate the files.

Once the data have been downloaded the screen to the right will be shown. This will confirm whether or not there is 100% coverage of base station data available for all files. If there is not the download may have been interrupted and so it will need to be repeated Select **OK** when done.

The screen to the right will be opened which gives the Reference Station position. Select **OK**.

You will be returned to the main differential correction window. Select **OK** to start differential corrections. During the process a progress screen similar to that to the right will be displayed.

At the end of the process a summary screen will be shown giving the success/failure rates for the survey. The bottom left shows a successful analysis; bottom right unsuccessful.

Successful Correction

Unsuccessful Correction

When there is not a 100% success rate select the **More Details** button to find the reason why. Usually, this is because of the distance from the base station. During the surveys the rover receiver saw certain satellites that the base station could not see and thus, the data could not be corrected. This can be avoided by setting the **Elevation Mask** option in the

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ROMDAS software to a higher value.

Unsuccessfully corrected files must be imported to the GIS in raw format, saved in the correct projection, and then manually corrected as necessary.

Exporting Differentially Corrected Files

The differentially corrected files are saved with the .COR extension. These need to be exported as ASCII text files so that they can be read by ROMDAS.

- Select **Utilities|Export** and the window the right will be given.
- Ensure that all the files are selected.

  NOTE: Be sure to use only the .COR differentially corrected files, not the raw .SSF files. The export will not work if .SSF files are selected.

- Ensure that the 'ROMDAS Configurable ASCII' setup defined earlier is selected
- Select **OK** to start the export. A progress screen such as that shown to the right will be displayed.

At the end of the export a screen will be displayed showing the success (or otherwise) of the export.

11.7 Data Processing

Overview

The extent of data processing of GPS data depends upon the nature of the survey. Figure 11.4 shows the steps involved in processing the ROMDAS survey data for the case study described in the report 'Using ROMDAS for Network Referencing and Mapping Surveys', which is on the ROMDAS CD and available for download from www.ROMDAS.com. The procedure was as follows:

- A preliminary network was created using assumed survey distances for each segment. These were replaced with the actual measured distances.
- The survey data were used to create a 'Segments' file. This file contains data on the road segments between nodes, the link numbers, *etc*.

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- The centreline data were post-processed with Trimble Pathfinder Office v 2.70 to differentially correct the readings using a base station.
- The centreline data were imported to ROMDAS to replace the raw survey data. Missing co-ordinates were estimated using the ROMDAS gyroscope data.
- The ROMDAS survey data were processed to create a series of points representing the nodes. These were comprised of the node label, x, y co-ordinates. These were **uncorrected** since during the survey it was not possible to drive to the exact centre of the node and take a reading. The actual node positions were manually established later in the GIS. The data were formatted to be imported to MapInfo.
- The processed ROMDAS data were used to create MapInfo import files using the ROMDAS Road Management System.

The final two steps entailed creating the spatial network. The node and centreline data were imported as two layers into MapInfo. The data were then manually corrected to ensure the correct topology and ensure network continuity.

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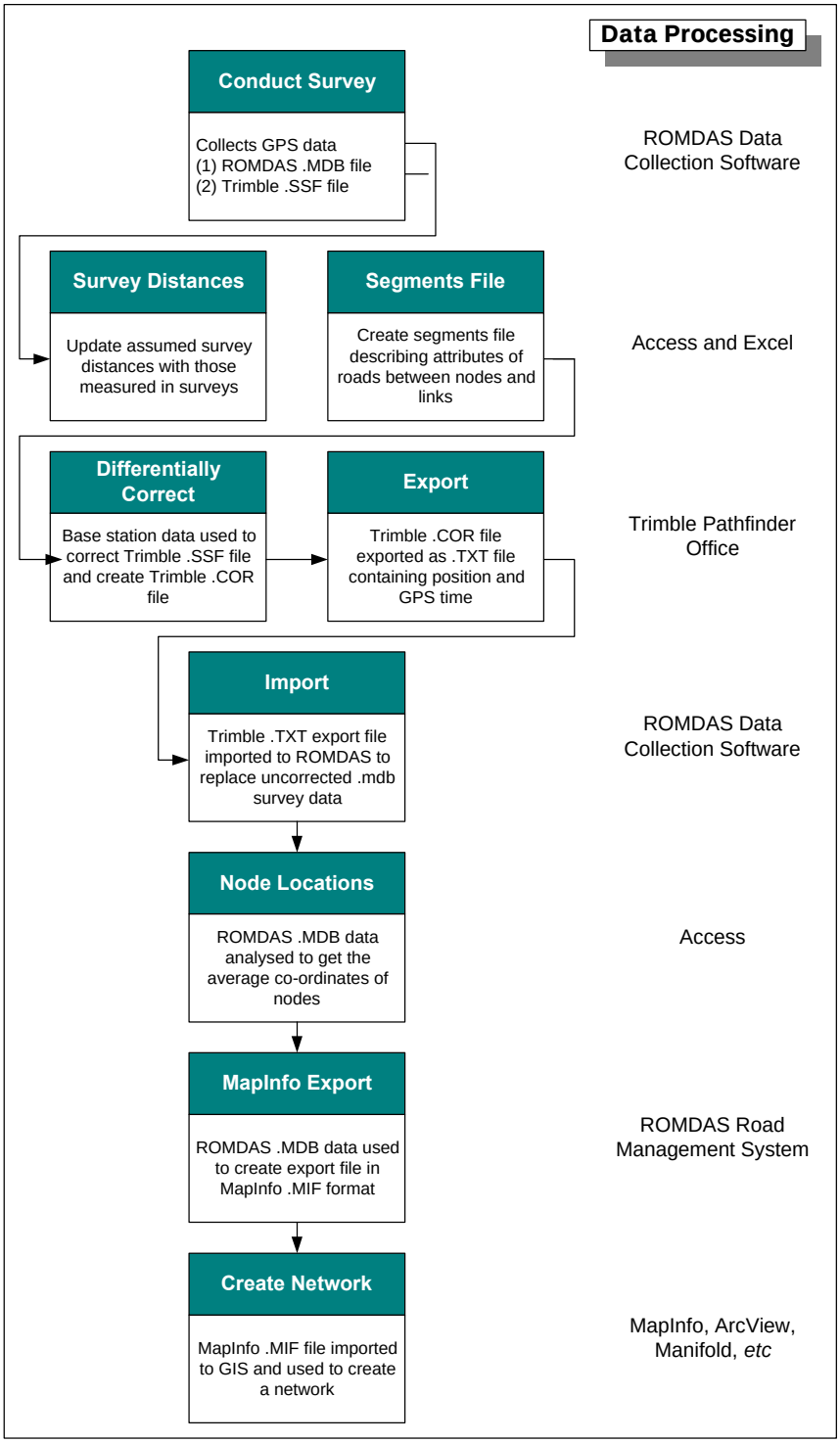
Data Processing
Conduct Survey
Collects GPS data
(1) ROMDAS .MDB file
(2) Trimble .SSF file
ROMDAS Data Collection Software
Survey Distances
Update assumed survey distances with those measured in surveys
Segments File
Create segments file describing attributes of roads between nodes and links
Access and Excel
Differentially Correct
Base station data used to correct Trimble .SSF file and create Trimble .COR file
Export
Trimble .COR file exported as .TXT file containing position and GPS time
Trimble Pathfinder Office
Import
Trimble .TXT export file imported to ROMDAS to replace uncorrected .mdb survey data
ROMDAS Data Collection Software
Node Locations
ROMDAS .MDB data analysed to get the average co-ordinates of nodes
Access
MapInfo Export
ROMDAS .MDB data used to create export file in MapInfo .MIF format
ROMDAS Road Management System
Create Network
MapInfo .MIF file imported to GIS and used to create a network
MapInfo, ArcView, Manifold, etc

Figure 11.4: Steps Involved in Creating Spatial Network

ROMDAS Data Processing

The ROMDAS data processing is automated. The user selects the folder and indicates whether to use the gyroscope to estimate missing data (yes) and to replace the raw survey data with differentially corrected data (yes).

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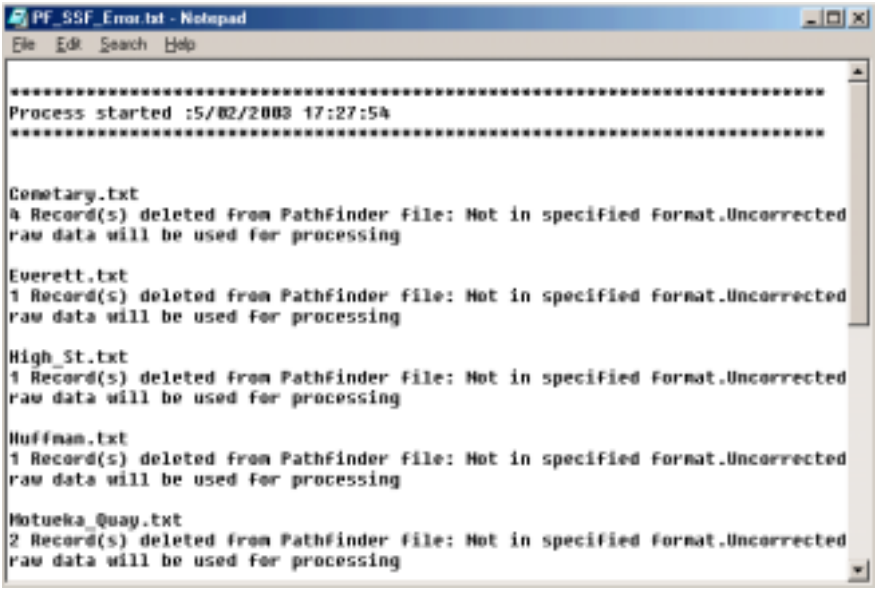
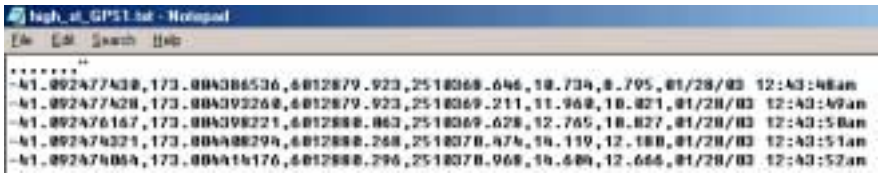
For each file in the folder, ROMDAS opens the survey data file and creates a new table called Processed_GPS containing the results of the data processing.

The raw GPS data are matched to the differentially corrected .TXT export files using the GPS time. The differentially corrected co-ordinates are then written to the Processed_GPS file along with the other data for that point (*eg* chainage).

During this operation if there are any errors in the .TXT files, these are written to an error log (PF_SSF_Error.txt). These errors are invariably due to problems with the surveyed .SSF file being corrupted. An example of the error log is below.


PF_SSF_Error.txt - Notepad
File Edit Search Help
****
Process started :5/02/2003 17:27:54
****
Cemetary.txt
4 Record(s) deleted from PathFinder file: Not in specified format.Uncorrected raw data will be used for processing
Everett.txt
1 Record(s) deleted from PathFinder file: Not in specified format.Uncorrected raw data will be used for processing
High_St.txt
1 Record(s) deleted from PathFinder file: Not in specified format.Uncorrected raw data will be used for processing
Huffman.txt
1 Record(s) deleted from PathFinder file: Not in specified format.Uncorrected raw data will be used for processing
Motueka_Quay.txt
2 Record(s) deleted from PathFinder file: Not in specified format.Uncorrected raw data will be used for processing

The differentially corrected export files for each of the roads in the error should be reviewed. With some files errors were can due to a single line of bad data (see below), others may be devoid of data or missing.



Where possible the files should corrected by deleting the bad data, and then reprocessed.

With less than 100% success with the differential corrections errors it is necessary to use a two-stage process to import the data into the GIS. This is because the differentially corrected Trimble data were processed into a new projection (*eg* NZMG) whereas the raw data were in WGS84 Latitude/Longitude. Thus, one needs to import the two sets of data separately to the GIS using the appropriate import projection data.

An alternative approach would be to import all data into the GIS as WGS84 Latitude/Longitude, and to do the projection transformations

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there instead of in Trimble Pathfinder Office. However, it has been found that some GIS systems do not transform the data as accurately as Trimble Pathfinder Office so the two stage approach is recommended.

MapInfo Files

The ROMDAS data collection software will create a series of Access files with the spatial data. For creating MapInfo export files suitable for use with the GIS it is necessary to purchase the ROMDAS Road Management System (RMS).

As discussed above, it is often necessary to use a two-stage process to import the data. In Stage 1, the data which were successfully differentially corrected were imported in the projection used with Trimble Pathfinder Office. In Stage 2, the remaining data were imported using WGS84 Latitude/Longitude. This two-stage approach was simplified by creating separate Segment files, each including the roads to be included with Stage 1 or Stage 2. The roads below are those that were imported in Lat/Long WGS84 instead of NZMG.

Survey_Desc	Survey_ID	Survey_File	Segment_Number	Link_ID	Link_Name
Cemetary St	Cemetary	Cemetary	1	L-008	Cemetary St
Everett St	Everett	Everett	1	L-018	Everett St
Everett St	Everett	Everett	2	L-018	Everett St
Huffman St	Huffman	Huffman	1	L-035	Huffman St
Motueka_Quay	Motueka_Quay	Motueka_Quay	1	L-054	Motueka_Quay_End
Motueka_Quay	Motueka_Quay	Motueka_Quay	1	L-055	Motueka_Quay
Motueka_Quay	Motueka_Quay	Motueka_Quay	2	L-055	Motueka_Quay
Old_Wharf Rd	Old_Wharf	Old_Wharf	1	L-059	Old_Wharf Rd
Old_Wharf Rd	Old_Wharf	Old_Wharf	2	L-059	Old_Wharf Rd
Old_Wharf Rd	Old_Wharf	Old_Wharf	3	L-059	Old_Wharf Rd
Old_Wharf Rd	Old_Wharf	Old_Wharf	4	L-059	Old_Wharf Rd
Trewavas St	Trewavas	Trewavas	1	L-082	Trewavas St
Trewavas St	Trewavas	Trewavas	2	L-082	Trewavas St
Wharf Road	Wharf	Wharf	1	L-090	Wharf Road

In order to create the .MIF and .MID files it was necessary to define certain options in the RMS. This was done on the three tabs located under **Tools|Utilities|GPS Data Processing|Generate Map Data**.

The first tab (see right) defines three items:

- whether the files are for ROMDAS for Windows or ROMDAS for DOS
- The folder containing the processed ROMDAS data files
- Whether to analyse all files or to use the Segment File for the list to include

The Segment File **MUST** be in a fixed format, and this can be created using the **Create Template** button. An Excel workbook will be created, with the appropriate headings for each column. In creating the file the Segment_ID must be unique for each link.

An important advantage to creating a segment input file is that the data in

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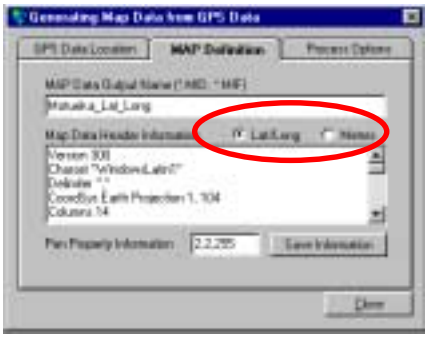
the file will also be used to populate the various fields in the .MID file, and thus be available in the GIS.

The **Map Definition** tab is where the file name, MapInfo header data and line properties are entered.

There are two settings: Lat/Long and metres (see right). Depending upon which is selected, there are different data created for the MapInfo header.



In this case study, since the differential corrections resulted in some files not being corrected, and thus being left in Lat/Long, it was necessary to import two sets of data.

The **Pen Property Information** is used to define the width, pattern and colour of the lines. The format of the clause is width, pattern, colour. A value of 2 for the thickness, 2 (solid) for the line and 255 (blue) were adopted.

The **Process Options** tab is the final entry where it is necessary to define the specific options for creating the centreline.

- The **Coordinate Value Shift** option is used to arithmetically shift all data by the specified number of metres. This is used when, for example, there is an error in a layer that the data are being displayed against (*eg* an incorrectly rectified image).
- The **Last LRP** options pertain to how the data at the end of a survey run are considered.
  - Normally, one conducts a survey and enters the location of the last LRP. This is followed by ending the survey.
  - Some surveys record the end of the survey with a temporary LRP. This data should not be included with the survey data.
  - In some instances, it is possible to record the LRP in advance of its correct position, and thus the end of the road. In this instance the third option is used to assign the data beyond the LRP to the previous segment.
- The option to **Break Lines by LRP** is used to create unique segments between each LRP. These segments are given a sequential segment number and allow for other data to be linked at the segment level.

With the options set the **Generate** button was used to generate the .MIF and .MID files. Examples of these files are below.

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```
1,"Clay","Clay St","Clay",1, "%-010","Clay St","Clay_1","H157-H158","H157","H158",0, 132,132
2,"Clay","Clay St","Clay",2, "%-010","Clay St","Clay_2","H158-H159","H158","H159",132, 258,126
3,"Adair","Adair St","Adair",1, "%-002","Adair St","Adair_1","H123-H124","H123","H124",0, 14,14
4,"Adair","Adair St","Adair",2, "%-002","Adair St","Adair_2","H124-H126","H124","H126",14, 77,63
5,"Adair","Adair St","Adair",3, "%-002","Adair St","Adair_3","H006-H126","H006","H126",77, 135,58
```

Example of .MIF File

```
Version 300
Charset "WindowsLatin1"
Delimiter ","
CoordSys Earth Projection 18, 31, "m", 173, -41,
Columns 14
  Unique_ID Integer
  Survey_ID Char(40)
  Survey_Desc Char(60)
  Survey_File Char(60)
  Segment_Number SmallInt
  Link_ID Char(40)
  Link_Name Char(60)
  Segment_ID Char(60)
  Segment_Name Char(60)
  Segment_Start_Node Char(20)
  Segment_End_Node Char(20)
  Segment_Start_m Float
  Segment_End_m Float
  Segment_Length Float
Data

Pline 6
2511908.604 6010886.471
2511908.618 6010887.056
2511910.068 6010882.657
2511905.582 6010884.506
2511902.927 6010882.825
2511900.04 6010880.87
     Pen (2,2,255)
```

Example of .MID File

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12 Rut Depth Surveys

12.1 Introduction

Overview

The ROMDAS transverse profile logger (TPL) is designed to measure the transverse profile of the pavement. These measurements are used to calculate the rut depth. The TPL consists of the following:

- UMSA (ultrasonic measurement sensor arrays) nodes;
- master controller;
- aluminium housing for the UMSA nodes which is affixed to the front of the vehicle. There is a 2 m main section and two 0.5 m 'wings' which extend beyond the main section.

Each UMSA node consists of 5 ultrasonic sensors and their associated circuitry in an environmentally protected housing. The sensors are spaced at 100 mm intervals and will measure the distance to pavement with an accuracy of ± 1.0 mm[15]. The main section contains four UMSA nodes while the wings each contain one UMSA node each. A total of 30 sensors are therefore available when the main section and both wings are being used. A 31st sensor is fired at a fixed distance target to correct for ambient conditions.

The TPL does not do real time processing of the data. Instead, the data is downloaded to the computer during the survey and stored for post-processing. This allows for a more detailed data analysis than is possible with real-time systems.

The following data are recorded each time a measurement is made:

- the vehicle chainage in m;
- the vertical elevations of each sensor above the pavement;
- the fixed distance sensor measurement applying to each reading.

The transverse profile measurement is therefore characterised by a pair of sensor numbers and elevations — or a series of x-y co-ordinates when the sensor number is replaced by the location of the sensor relative to the first sensor. Since there may be some variations with the spacing between each UMSA node, these spacings are defined under the ROMDAS **SETUP|OPTIONS|TPL** menu (see Section 12.2). In the discussion and examples which follow it is assumed that the distance between UMSA nodes is 100 mm.

[15] This is based on static testing of the system with objects of known heights. The confidence intervals for the means were < 0.5 mm with 95% confidence. Allowing for errors in the 'real world' the measurements can be taken to be ± 1.0 mm. Working papers on the testing are available at www.ROMDAS.com in the download section.

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The y co-ordinates consist of the time it takes for the ultrasonic signal to travel to the surface and return to the sensor. The data are downloaded to the computer these are converted to the actual distance in mm. Data are stored along with the chainage where the measurements were taken. Details of the file structure are given in Chapter 17. Appendix D gives full details on the TPL serial communication protocols.

The following sections describe the design of the TPL and how rut depths and distortion are calculated from the TPL data.

Theory

The ROMDAS TPL operates with up to 30 ultrasonic sensors spaced at nominal 100 mm intervals. The individual UMSA node units are connected to each other and to the 'Master Controller' in series. The Master Controller is the interface between the UMSA nodes and the computer.

The TPL Master Controller is connected to the computer via an RS-232 serial cable. Since the ROMDAS hardware interface also must be connected via an RS-232 cable it is necessary to have two RS-232 ports available on the computer. For those computers with only one RS-232 port, a PCMCIA RS-232 card must be used.

Based on a sampling interval defined by the user, the computer sends a trigger signal to the master controller consisting of the current chainage (in m). To avoid interference effects between adjacent sensors, the same sensor is fired in all UMSA nodes at the same time. A firing of the other sensors then follows until all five sensors in the UMSA node have been fired. The staggering of the firings means that the resulting transverse profile is not from the same point in space but are instead a composite formed from the five firings. This is illustrated below.

The firing of all sensors in all UMSA nodes takes approximately 0.12 s, with an additional 0.13 s to store the data. The total longitudinal distance between sensors 1 and 5 in each array therefore depends upon the speed of the vehicle. The table below shows the theoretical distance over which the sensors are fired as a function of the vehicle speed. In practical terms, if you are travelling below 70 km/h 5 m sampling is possible; above that 10 m.

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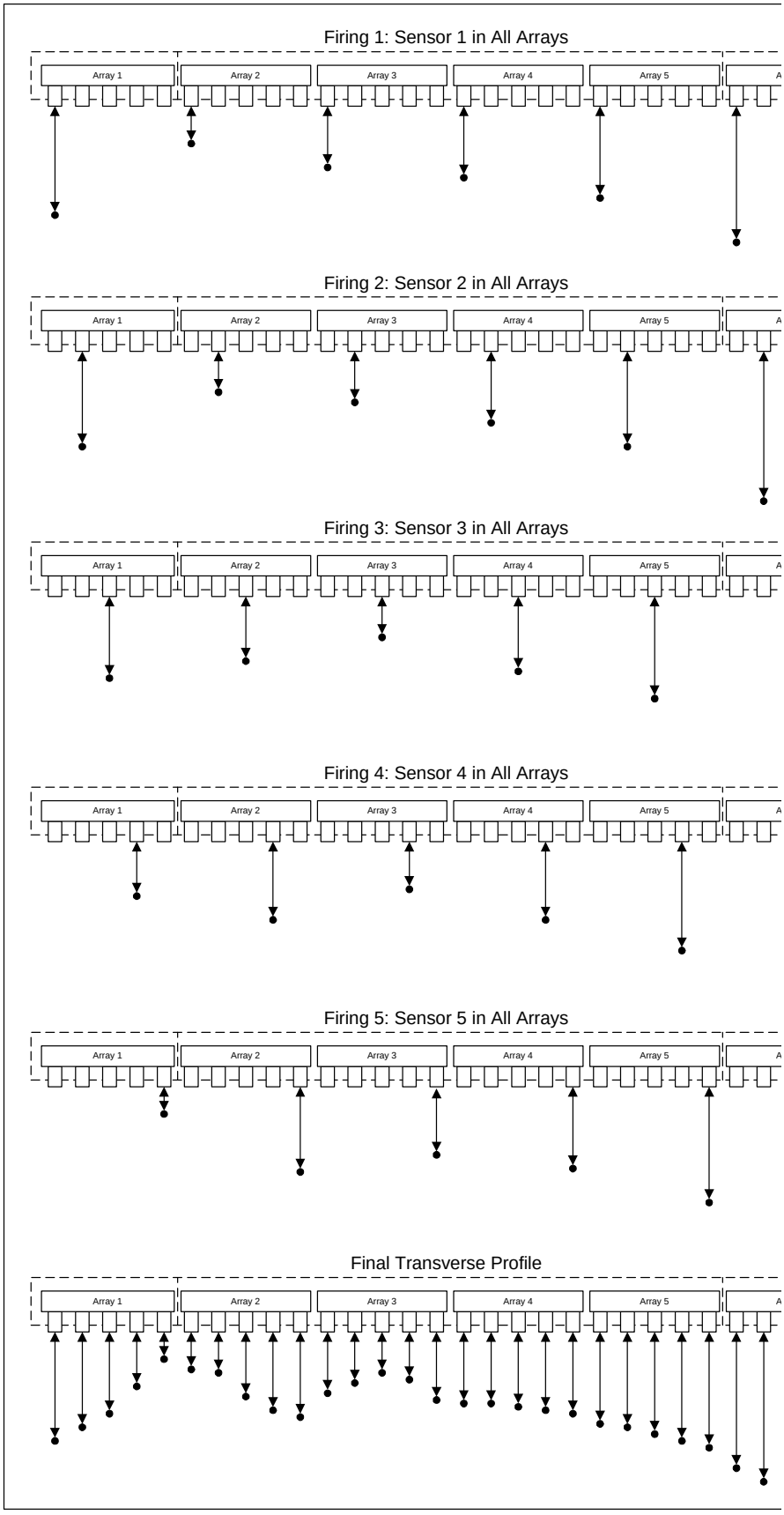

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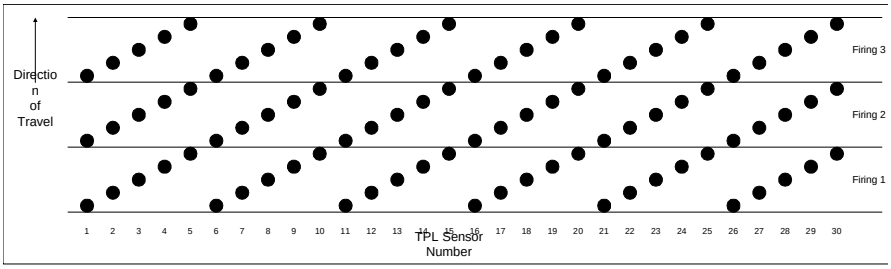

Transverse Profile Measurement Locations

Speed (km/h)	Velocity (m/s)	Distance for Firing (m)
5	1.4	0.3
10	2.8	0.7
20	5.6	1.3
30	8.3	2.0
40	11.1	2.6
50	13.9	3.0
60	16.7	4.0
70	19.4	4.6
80	22.2	5.3
90	25.0	6.0
100	27.8	6.6

The TPL has a cover which is used to protect the sensors from the environment. This should be closed at all times except when a survey is in progress.

Before commencing a survey a series of measurements should be taken to 'zero' the sensors. This is done to obtain the relative elevations of each sensor above a straight edge. The measurements should be made using the **Setup|Calibrate|Calibrate TPL|Create Datum Level** option (Section 5.5). The vehicle should be parked on a level section of road and a straight edge placed below the TPL. When the survey data are processed the elevations are corrected using the datum level values.

12.2 TPL Setup Options

TPL Settings

The TPL options are defined under **Setup|Options|TPL**. This option will only be active if you have purchased a TPL (unless you are using the evaluation software which has all options available for 30 days). When selected, the form below will be shown.

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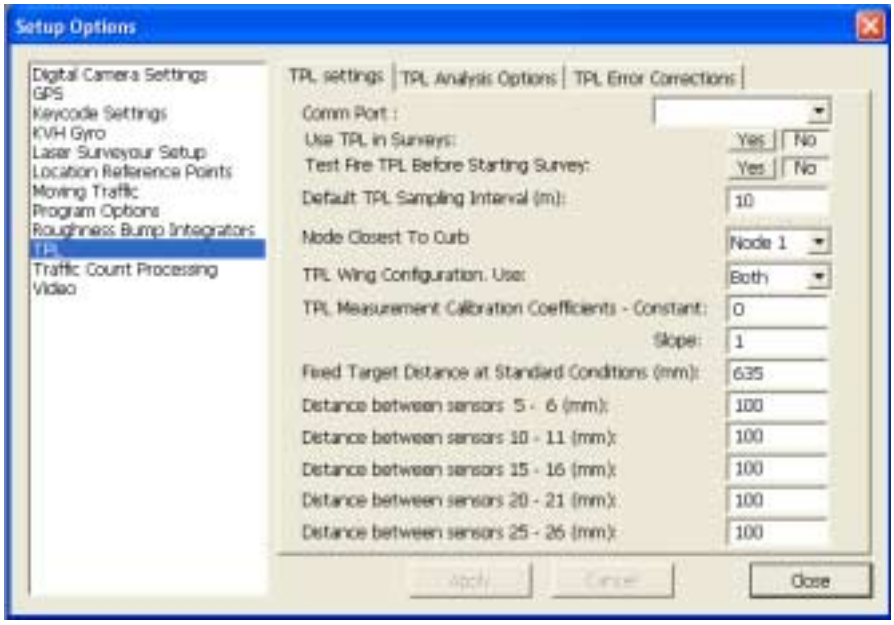

- **Use TPL in Surveys** This defines the setting on the survey opening screen. If you are always using a TPL set this value to Y.
- **Test Fire TPL before starting Survey**. This option displays the readings of the TPL sensors before the survey starts. It is a useful check that all sensors are working since the TPL does not return error messages during the survey
- **Default TPL Sampling Interval (m)**. This is the distance in m where transverse profile measurements will be taken. Since the firing of the sensors is staggered (see section 12.1), the first sensor in each array is fired at this distance. The subsequent sensors are fired within about 0.1 ms of this distance.
- **Node closest to Curb**. The TPL is shipped with Node 1 on the right hand side of the vehicle. The software needs to know which node (1 or 6) is closest to the curb in order to correctly report the wheelpaths. The node closest to the curb will change depending on whether you drive on the left or right hand side of the road in your country.
- **TPL Wing Configuration**. The user can specify which wings are used in the survey. Either None, 0 - 5, 25 – 30 or Both.
- **TPL Measurement Calibration Coefficients (Constant and Slope)**. The user can calibrate the TPL readings by comparing the measured output with a known distance. This is done as described in Appendix C and results in a linear equation between the measured and actual distance. The user enters the slope and constant of this regression here.
- **Fixed Target Distance at Standard Conditions (mm)**. As described in Appendix C the TPL has a sensor firing at a fixed target. The user enters the distance to the fixed target (in mm) under the standard conditions. These standard conditions represent a base altitude, temperature and atmospheric pressure. The fixed target value is established during the **TPL Distance Calibration.**

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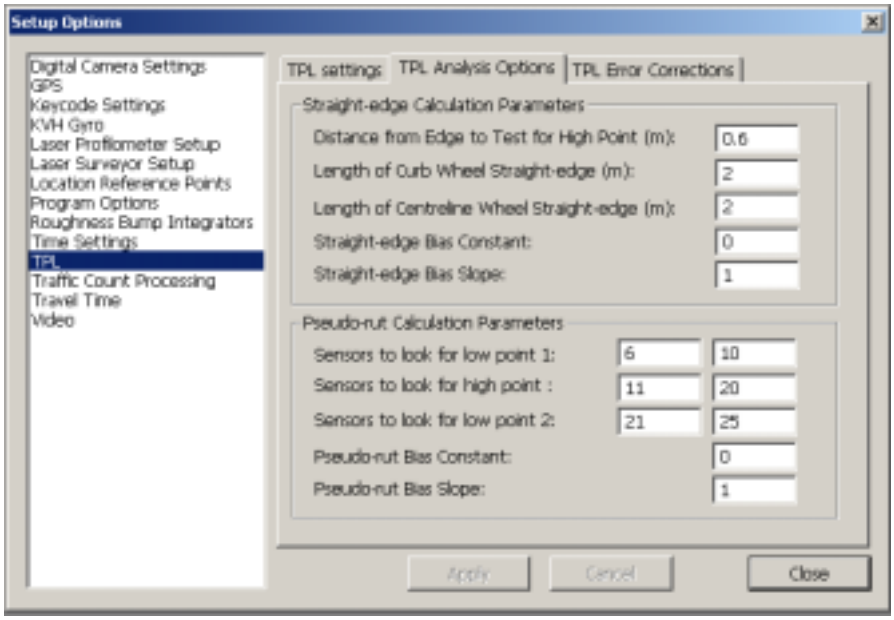
Analysis Options



As described in Chapter 12.2, there are two methods for calculating rutting:

- **Straight-edge**. The rut depth is calculated under a user-defined simulated straight-edge.
- **Pseudo-rut**. This is the maximum difference in height between the wheelpath and the crown between the wheelpaths

Straight-edge rut depths are really only meaningful when the rut bar extends over the full width of the ruts. Thus, if one is using only the 2 m section it may be appropriate to use pseudo-ruts.

- **Distance From Edge to Test for High Point**. The rut depth analysis algorithm tests a variety of possible starting points to establish the high point for the straight edge (see Chapter 0). This sets the test for the first high point to within 0.6 m of the pavement edge. This value can be increased to 1.2 m.
- **Length of Straight Edge**. The rut depths are calculated under a user-defined straight edge length. This can be any length from 0.2 to 2.5 m in 0.1 m intervals. Different straight edge lengths can be used in the left and right wheelpaths, although usually the same length should be used.
- **Straight Edge Bias**. These values are provided to allow for a correction for a bias in the TPL measurements. It has been found that on some heavily textured surfaces there is a bias of 3 mm in the predictions. The data here are used in a regression equation to adjust the predictions. They should be set after a calibration against manual measurements based on local conditions.
- **Puesdo Rut Calculation Parameters**. These entries give the sensor numbers where the high and low points will be located for calculating the pseudo-rut depths. Here, only the main bar is used so the rutting is assumed to be in the first 5 sensors to the left (6-10) and the last 5 sensors at the right (21-25). The high point will be between sensors

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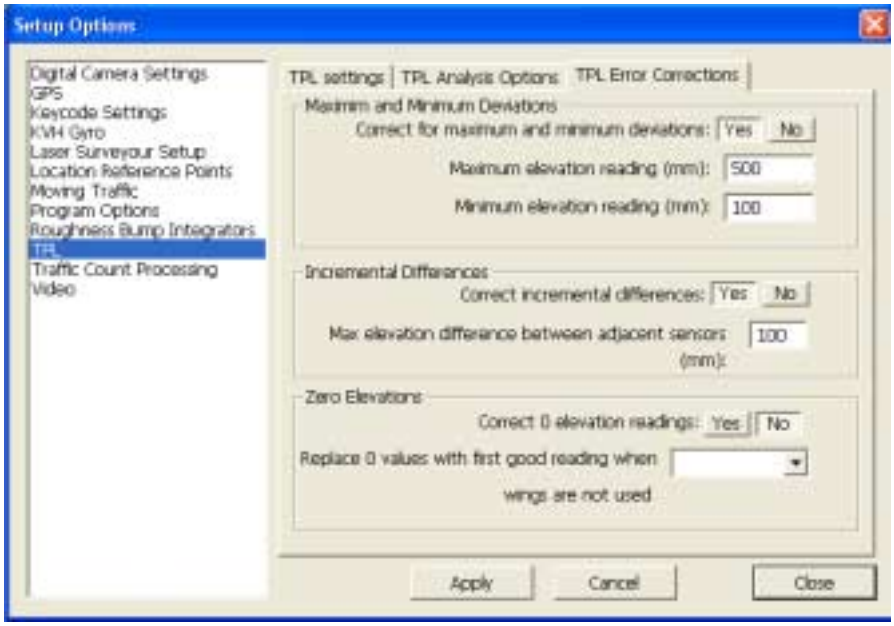
11-20. As with the straight-edge, calibration coefficients are provided to correct for any biases when compared to a straight-edge measurement.

Error Corrections



The TPL Error Corrections are applied when processing the raw TPL data. The dialog above shows the corrections that can be made to the data.

- **Correct for Maximum and Minimum deviations.** The TPL sensors may occasionally 'range out' which sees them giving excessively high values. Less frequent are excessively low values. Since these will lead to silly estimates of the rut depth they should be corrected. The values entered here should represent the maximum and minimum likely values expected and any reading exceeding these is treated as a bad reading to be corrected. They should be based on the height of the TPL sensors above the pavement and the expected rutting levels.
- **Correct incremental differences**. Unless you are dealing with a highly discontinuous pavement, or going over the pavement edge, there will not be large incremental differences between adjacent sensors. If the values are outside of the limit set here the reading is treated as a bad reading to be corrected.
- **Correct 0 Elevation Readings**. When a sensor fails it returns a zero elevation. Setting this option to 'Y' sees these readings corrected.

When a TPL reading fails one of the first three tests and corrections have been requested, it is treated as a bad reading. The data are corrected by linearly interpolating the elevations from the adjacent good readings.

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12.3 Data Processing

Overview

After the TPL data have been downloaded it is necessary to process the data before analysis. This is done using the **DATA PROCESSING** option.

Before processing the data ensure that the appropriate data correction options are selected (Section 12.2).

The user is prompted to enter the name of the Datum Level file (Datum Table in TPL Calibration.mdb) created as described in Section 5.5. This provides the correction factors for each sensor relative to one another. The user then selects that raw TPL data file to be processed. The following processing is done to the data:

- **Standard Conditions**. Ultrasonics are influenced by temperature, altitude and barometric pressure. To correct for this, the TPL has a sensor which fires continuously at a fixed distance target. Thus, any variations in the readings of this sensor represent the effects of the above ambient conditions on the ultrasonics. The user defines the standard distance to fixed target (see Appendix C) and the ratio of the fixed sensor measurement to the standard distance is used to correct the data for ambient conditions.
- **Measurement Calibration Coefficients**. The data are then corrected for the measurement calibration coefficients. As described in Appendix C, these are created by comparing the TPL output to known distances and analysing the data to establish a linear relationship. The coefficients are entered as described in Section 12.2.
- **Relative Heights**. The datum level file contains the correction factors for each sensor relative to each other. These values are added to the individual elevations, after being corrected to standard conditions based on the fixed target measurement during the calibration.

To illustrate this process, consider the following example:

Standard Conditions - The standard distance of the fixed distance sensor is 200.0 mm
Measurement Calibration Coefficients - The distance calibration equation is 10.0 + 0.9 DISTANCE
Relative Heights - The relative height for the sensor is -2.0 mm and this was established with the fixed sensor reading 300 mm.
Sensor Readings (from TPL_Raw_xxx table) - The readings of the sensor was 302.0 mm with a fixed distance sensor reading of 222.0 mm.

1. Correct the raw data for ambient conditions:

   RAW_1 = 302.0 x 200.0/222.0 = 272.1 mm

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This means that although the sensor measured 302.0 mm, since the fixed sensor was over measuring by 11% (222.0/200.0) the true distance is 11% lower than the measured 302.0 mm – 272.1 mm.

2. Measurement Calibration Coefficients

The actual measurements at standard conditions is established as:

$$RAW\_2 = 10 + 0.9\ RAW\_1$$
$$= 10 + 0.9 \times 272.1 = 254.9 \text{ mm}$$

Although the instrument was measuring 272.1 mm the actual distance corresponding to that measurement is 254.9 mm.

3. Relative Distance

The relative distance for this sensor is -2.0 mm but this was at a standard condition of 300.0 mm. The actual relative distance is:

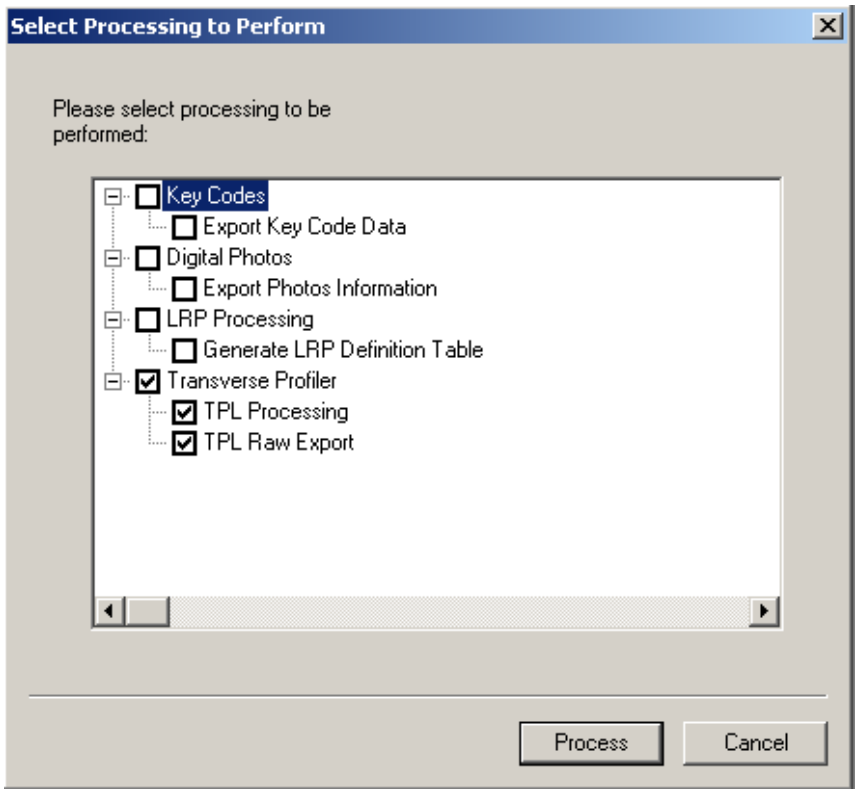
$$REL\_DIST = -2.0 \times 200.0/300.0 = -1.3 \text{ mm}$$

4. Final Elevation

The final elevation is the calibrated distance plus the relative distance:

$$ELEV = 254.9 - 1.3 = 253.6 \text{ mm}$$

Processing



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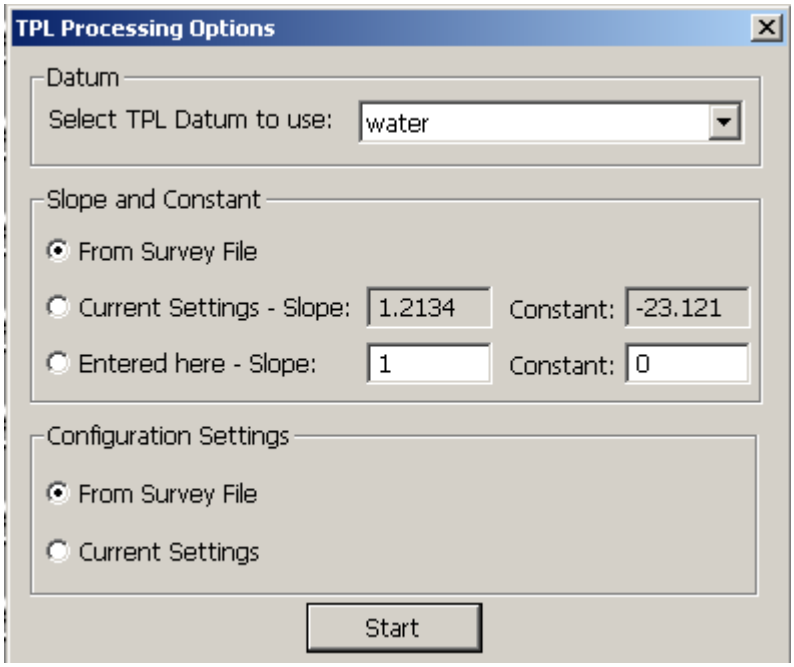

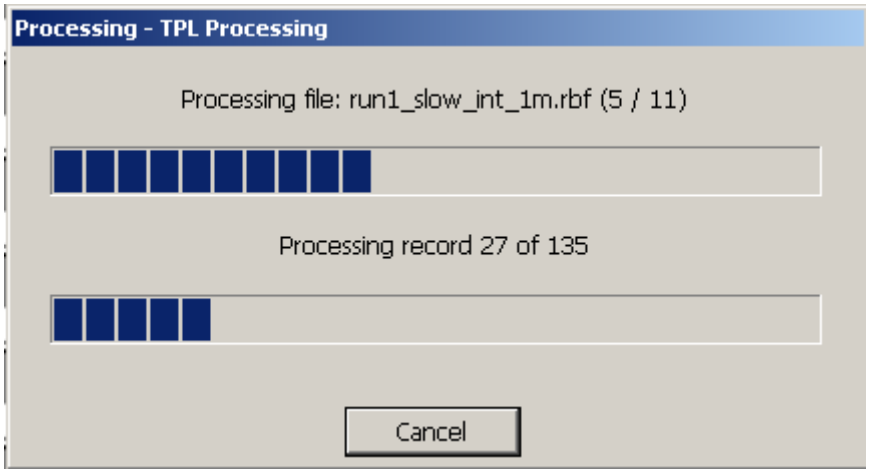

12.4 Analysing TPL Data

Overview

There analyses the TPL data and calculates the rut depth using two methods:

- Rut depth under a straight-edge
- Pseudo-rut depths

The raw TPL data may have ‘noise’ in the readings which may lead to a mis-estimate of the rut depths. As described in Section , the data can be smoothed using a 6th degree polynomial equation. This sees the equation fitted to the data (as in the figure to the right) and then the profile values predicted from the equation. The smoothed values are then used in all

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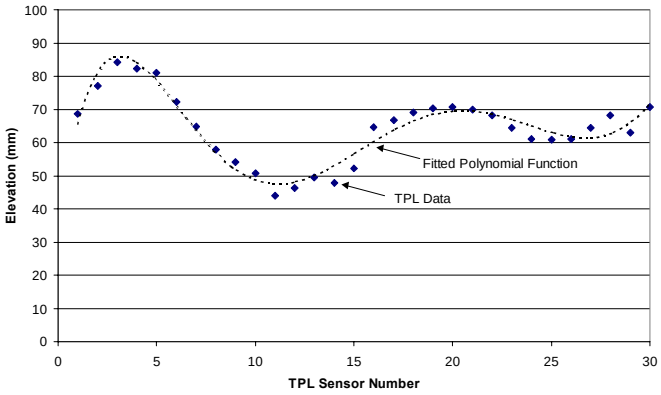
calculations. This option can be turned on or off by the user.



Rut Depth Under a Straight-Edge

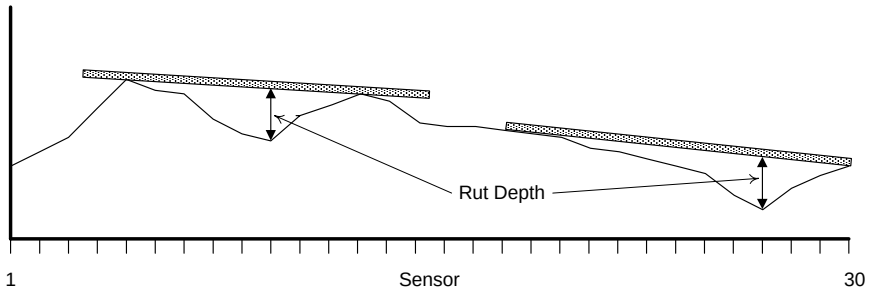
The transverse profile data are analysed to determine the rut depth under straight edge. The straight edge length is user-definable between 1.0 - 3.0 m. The analysis method is based on that developed for the US Strategic Highway Research Program (SHRP) by Hadley and Myers (1991)[16]. Two statistics are calculated:

- the rut depth under a user-defined straight edge; and,
- the transverse profile distortion.

Rut Depth

The rut depth algorithm can analyse any straight-edge length up to the 3.0 m, however, the straight-edge must be expressed in terms of multiples of 0.1 m.

When a straight-edge is laid over a wheelpath, it rests upon the two high points under its span. The rut depth is defined as the maximum vertical distance between the straight-edge and the pavement. This is illustrated in Figure 12.1 for two wheelpaths under a 1.2 m straight-edge and a hypothetical transverse profile.



16 Hadley, W.O. and Myers, M.G. (1991). Rut Depth Estimates Developed from Cross Profile Data. SHRP Long Term Pavement Performance Program Technical Memo AU-179, Texas Research and Development Foundation, Austin.

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Figure 12.1: Calculating Rut Depth from Transverse Profile

The analysis starts at sensor 1 which is the reading closest to the pavement edge. It progresses until the rutting in one wheelpath is established. It is then repeated for the second wheelpath starting at sensor 30 and moving downwards. If the 'wings' are not used the calculations start with sensors 6 and 25 respectively.

To illustrate the analysis process consider Figure 12.2-A which shows a set of hypothetical transverse profile elevations. The algorithm places the end of the straight-edge at a starting point. For each start point, the slopes are calculated between it and all successive points which would fall within the span of the straight-edge (e.g. 12 points for 1.2 m straight-edge). Figure 12.2-B illustrates this using Sensor 3 as the start point.

The maximum of these slopes is identified (Sensor 5 in Figure 12.2-B). Two criteria are used to establish whether or not this is a viable placement point for calculating a rut depth. If either of these are met the current starting point will not produce a rut depth and the analysis moves on to the next starting point. These criteria are:

- if the maximum slope is less than the slope between the start point and the preceding sensor;
- if the maximum point arises for the point adjacent to the starting point.

Once a viable placement point has been established, the vertical distance of all intermediate placement points are established. In Figure 12.2-C the start point is Sensor 5 and the maximum slope point is Sensor 12. Here, the maximum slope is that closest to the horizontal plane since all elevations are below that of Sensor 5. Figure 12.2-D shows the various possible rut depths for these two points.

For that starting point, the rut depth is the maximum of the vertical distances of all intermediate points. It should be noted that in calculating the rut depth the change in horizontal span due to tilting is assumed not to be significant.

For each possible starting point a maximum rut depth is derived. The largest of these values is taken as the rut depth for the wheelpath in question.

To minimise computation time, the number of possible starting points to analyse for each wheelpath can be limited. Hadley and Myers (1991) indicate that the maximum elevation usually arises within 0.6 m of the pavement edge so the default value used with ROMDAS is 0.6 m. However, this can be changed under the **SETUP|TRANSVERSE PROFILE LOGGER|TPL SETUP** menu (Section 12.2) up to 1.5 m.

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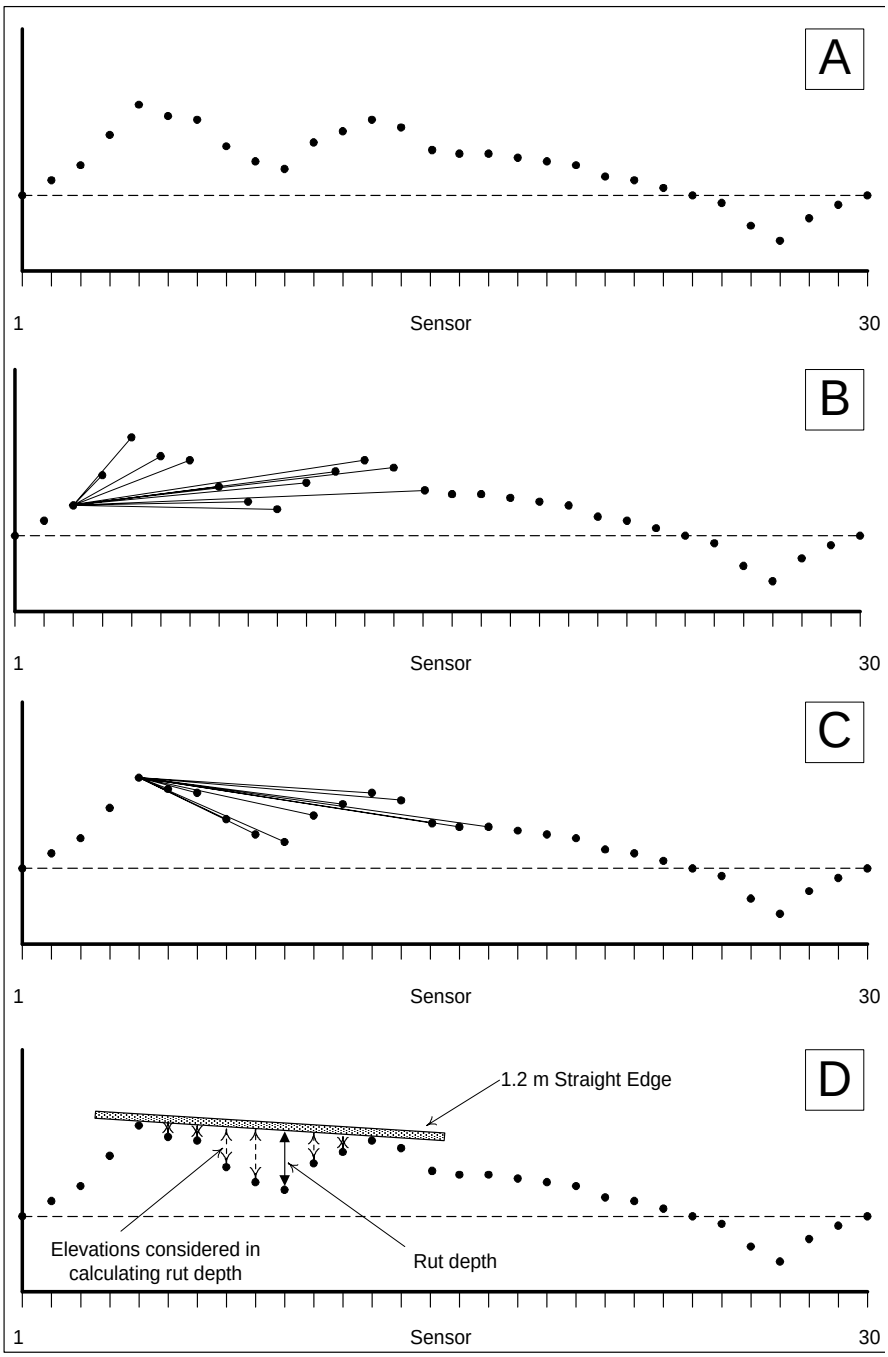

Figure 12.2: Example of Calculating Rut Depth

Transverse Profile Distortion

Hadley and Myers (1991) outline a method for using the distortions in the transverse profile to identify the potential source of rutting.

Distortion is defined as "the unit volumetric change in a [transverse] profile from its original cross slope orientation to that of the measured rutted configuration." There are two components of distortion:

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- uplift of the pavement gives rise to **positive** distortion. The uplift can be related to shoving within the asphalt surface layer(s), rutting in the upper pavement layers, or, possibly, soil swelling;
- **negative** distortion consists of a downward displacement of the pavement. This can be due to rutting in the upper pavement layer or, in extreme cases, subgrade effects.

The net transverse profile distortion is calculated using a finite element integration technique. A segment is defined as the product of the elevation and the distance between the sensors (i.e. based on the x-y co-ordinates). The distortion is the sum of the segments for all sensors.

The base cross profile is defined from the average elevations of the first three and last three sensors to minimise the impact of shoulder/edge drop off:

$$Y_L = \frac{Y1+2Y2+Y3}{4} \qquad Y_R = \frac{Y28+2Y29+Y30}{4}$$

where	Y_L	is the left elevation in mm
	Y_R	is the right elevation in mm
	Y1 to Y30	are the elevations of sensors 1 to 30 in mm

This approach is not used when the wings are not employed since it is assumed that there is little likelihood of edge drop off influences.

As shown in Figure 12.3, there are three cases which arise based on the net distortion:

- **negative** - if the rutting is severe and the distortion is almost completely negative this corresponds to a displacement of the pavement layers and the probable cause is subgrade rutting (Figure 12.3-A);
- **zero** - if the net distortion is approximately zero, i.e. it is evenly divided between upward and downward movement, this suggests rutting arising in the upper pavement layers (Figure 12.3-B);
- **positive** - when there is more uplift than displacement the net distortion will be positive which is indicative of shoving (Figure 12.3-C).

The distortion is reported both as an absolute value and as the ratio of positive to negative distortion.

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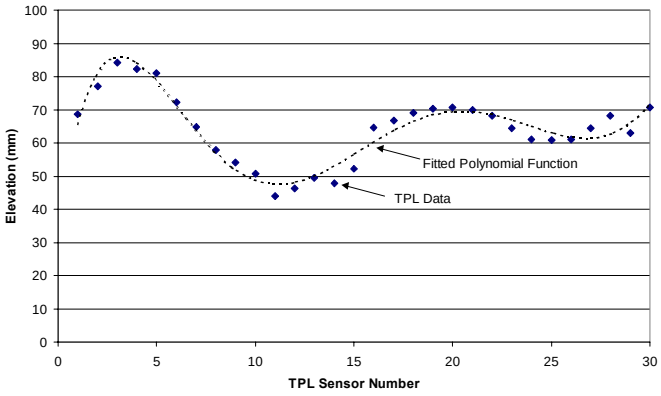

Pseudo-Rut Depths

As illustrated in Figure 12.4, 'pseudo-ruts' are defined as the difference (in mm) between the high point and the low points. This is a useful measure when only a portion of the rut bar is used—for example just the 2 m main section—and it has been found to give very repeatable results.

The pseudo-ruts are calculated for the left and right wheelpaths, and also averaged.

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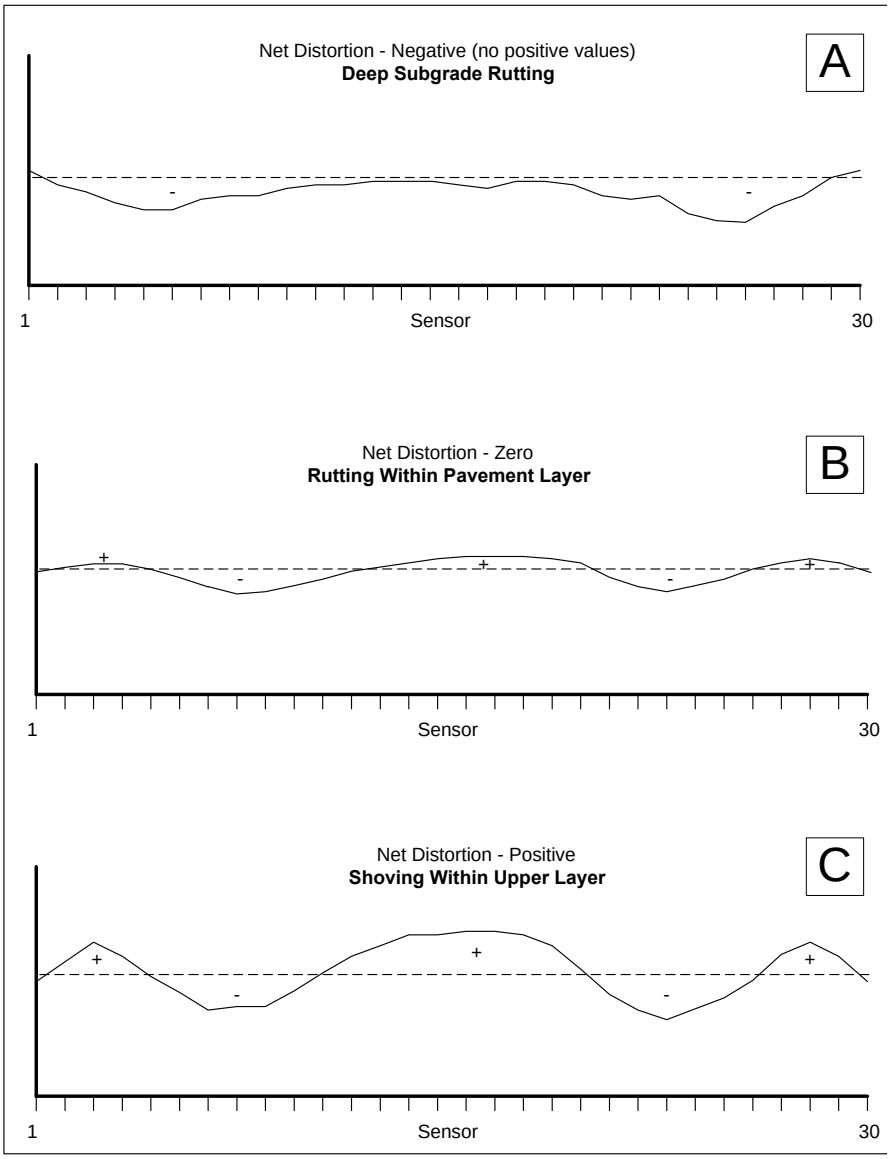

Figure 12.3: Pavement Distortion Possibilities

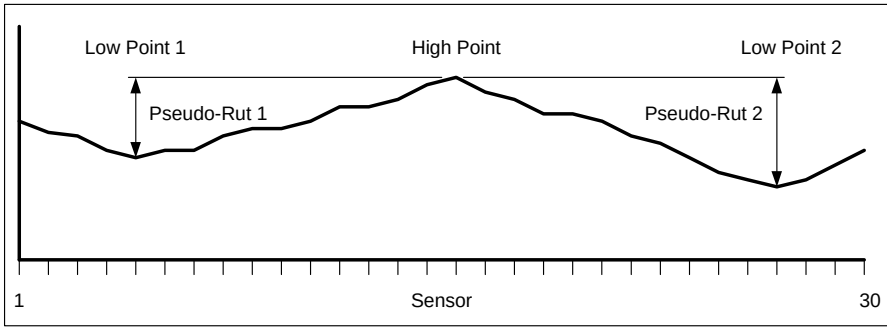

Figure 12.4: Definition of Pseudo-Ruts

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13 Moving Traffic Count Surveys

13.1 Introduction

Overview

Traffic count data have always been recognised as important in the design and planning process. Traditionally, most traffic count data have come from temporary or permanent traffic count locations. Either manual or automatic surveys are done which count the number of vehicles and convert these to an average daily traffic (ADT) or the average annual daily traffic (AADT).

An alternative approach, which lends itself to a ROMDAS survey, is to do a 'Moving Traffic Survey'. It works mainly on single and two-lane roads, although theoretically it should also work on multi-lane roads.

Moving traffic surveys are done by recording the number of vehicles travelling in the opposite direction. An Average Daily Traffic (ADT) is calculated which needs to be adjusted for day of week and month of year to get an AADT.

Theory

To calculate the ADT from a moving vehicle, consider the following proof where:

- X is the oncoming flow rate in veh/h
- So is the average oncoming vehicle speed in km/h
- Sr is the speed of the survey vehicle in km/h
- L is the distance travelled by the survey vehicle in km
- C is the number of vehicles counted travelling in the opposite direction in veh

The average headway (km/veh) between vehicles is So/X. The length of the observed traffic stream (in km) is C So/X.

The observed duration of the survey (in h) is given by L/Sr. Hence the length (km) of the traffic stream that has been observed is (Sr+So) L/Sr.

Equating these two expressions:

$$X = C\ So/[(Sr + So)\ L/Sr]$$

$$X = \frac{C}{L}\frac{1}{\frac{1}{So}+\frac{1}{Sr}}$$

If the survey vehicle travels at the same speed as the oncoming traffic, and it is assumed that there are no speed differences between classes, the above expression reduces to:

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$$X = \frac{C}{L}\frac{Sr}{2}$$

Since the duration of the survey is given by t = L/Sr, this can be expressed as:

$$X = \frac{C}{2\,t}$$

We assume that the total flow on the road is twice the flow in the opposing direction so the total flow is given as[17]:

$$Xtot = \frac{C}{t}$$

Or, for different survey vehicle speeds to oncoming traffic:

$$Xtot = \frac{C}{L}\frac{2}{\frac{1}{So}+\frac{1}{Sr}}$$

A calibration factor is used to convert to an ADT:

$$ADT = CFadt\ Xtot$$

The accuracy of the ADT count can be improved by classifying the vehicles and using the above expression to calculate the ADT by class and added to get the total ADT. It is not necessary to have the precise speeds of these other vehicle classes in the calculations. The speeds for the buses and trucks can be expressed relative to car speeds, for example as travelling 10 and 20 km/h slower respectively:

$$Xpc = \frac{Cpc}{L}\frac{2}{\frac{1}{So}+\frac{1}{Sr}}$$

$$Xhb = \frac{Chb}{L}\frac{2}{\frac{1}{So-10}+\frac{1}{Sr}}$$

$$Xtk = \frac{Ctk}{L}\frac{2}{\frac{1}{So-20}+\frac{1}{Sr}}$$

$$ADT = CFadt\,(Xpc + Xhb + Xtk)$$

where

Cpc	is the number of cars travelling in opposite direction
Chb	is the number of heavy buses travelling in the opposite direction
Ctk	is the number of heavy trucks travelling in the opposite direction
Xpc	is the flow for cars in veh/h
Xhb	is the flow for heavy buses in veh/h
Xht	is the flow for heavy trucks in veh/h
ADT	is the Average Daily Traffic

[17] An alternative approach is proposed by the TRL. They use the equation ADT = (C + y – z)/t where y is the number of vehicles that overtake the survey vehicle (Direction = 1) and z is the number of vehicles overtaken by the survey vehicle (Direction = 2). The theoretical basis for this equation is not known but it is postulated it is to correct for a departure from the median speed by the survey vehicle. The user can optionally apply this equation in processing survey data collected with ROMDAS, but it is recommended that the ROMDAS method described above be used.

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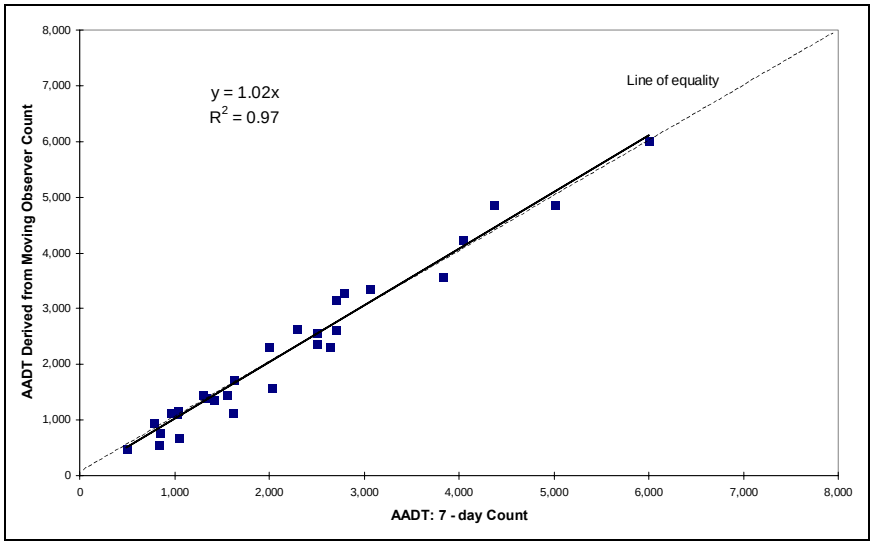
CFadt	is the ADT calibration factor based on time of day
L	is the distance travelled in km
So	is the speed of oncoming traffic in km/h
Sr	is the speed of the ROMDAS survey vehicle

Example of Predictions

How reliable is this method at calculating the ADT? The figure below shows the results of AADT derived from moving survey data from India, corrected for time of day and other factors, compared to the AADT from 7-day counts for the same road sections[18]. It can be observed that the moving survey method gave an excellent correlation with the 7-day counts.



Example of Moving vs 7-Day ADT from India

13.2 Adjustment Factors

Overview

The traffic count flow profiles are used to convert the moving traffic survey data to an ADT and an AADT. There are two corrections which are required:

- **ADT Calibration Factor**: used to correct for the time of day and duration of the survey
- **AADT Adjustment Factor**: used to correct for the day of week and month of year of the survey.

[18] Bennett, C.R. and Paterson, W.D.O. (1999). *HDM Calibration Reference Manual*. Report to the International Study of Highway Development and Management Tools, PIARC, Paris.

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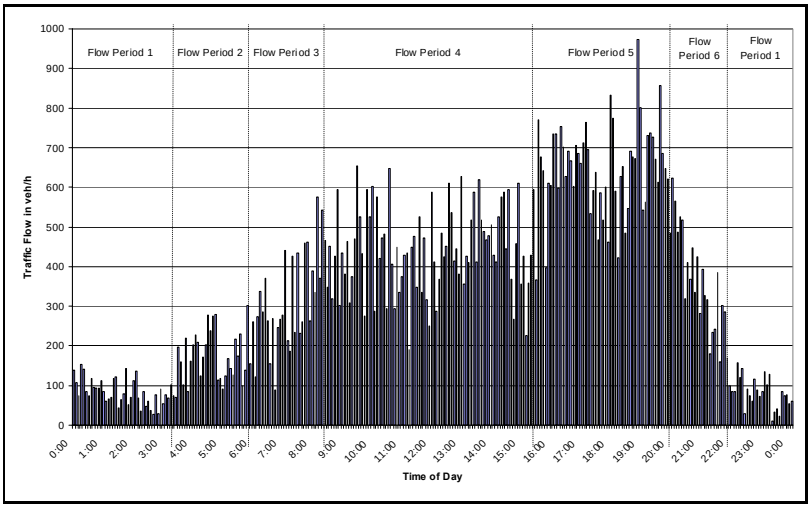
ADT Calibration Factor

The ADT Adjustment Factor (CFadt) is used to convert the hourly flow estimate to an ADT. It should be noted that the factor is generally dependent upon the type of road being surveyed. As a general rule, they will be different for urban and rural roads, and different roads in your hierarchy (*eg* residential, collector and arterial).
The traffic flows vary over the day. The figure below shows the hourly flows (veh/h) over a 24 h period based on 5 minute intervals for a road in Thailand. The direction monitored was out of town so the flows are low during the morning peak and increase during the day, reaching their highest during the afternoon peak.



Example of Daily Flow Profile

On the basis of the flows, six periods with relatively constant flow were identified. The flows during these periods are given in the table below. Dividing the flow by the length of each period gives the average hourly flow in veh/h. The total number of vehicles observed (ADT) was 8076 veh/day. The adjustment factor for each of the flow periods is therefore given by the ADT divided by the hourly flow. These are given in the right column. Thus, an hourly flow measured between 06:00 and 08:30 should be multiplied by 28 to convert it to an ADT.

Start	End	Observed Flow (vehicles)	Hourly Flow (veh/h)	Adjustment Factor to ADT
22:00	03:30	389	71	114
03:30	06:00	398	159	51
06:00	08:30	733	293	28
08:30	15:30	2986	427	19
15:30	20:00	2857	635	13
20:00	22:00	713	357	23
	ADT	8076		

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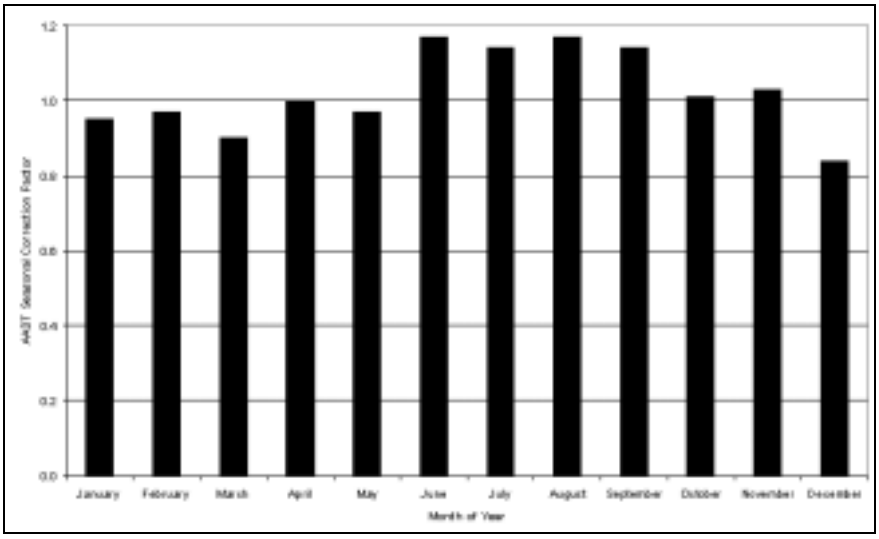
AADT Adjustment Factor

As with regular traffic counts, ADT also needs to be converted to an AADT using correction factors which are based on the month of year and, optionally, the day of week.

The figure below is an example of AADT seasonal correction factors from Gujarat, India. The traffic flows are lowest during the monsoon season from June-September so counts taken during these periods are multiplied by a factor greater than 1 to convert them to an AADT.



AADT Seasonal Correction Factors from Gujarat, India

The conversion is done as:

$$AADT = CFaadt\ ADT$$

where CFaadt is the AADT seasonal correction factor

The following sections describe defining CFadt and Cfaadt in ROMDAS.

Defining ADT Calibration Factor

Select **Setup|Survey Setup Files|ADT Calibration Factor**. The screen to the right will be shown.

The name of the table to store the ADT profile in must be entered and the **Create Table** button selected. This will create the table. It will be available from the drop-down list as shown to the bottom right.

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The **Start Time**, **End Time**, and ADT Factor are then entered as shown to the right. The **Insert** key is used to save the data. When the data are entered, select **Exit**. Records can be changed using the **Update** button.

These data are used to multiply the **average hourly** flow to convert it to an AADT. Thus, if an hourly flow of 20 veh/h was observed between 22:00 and 03:30 the ADT would be 2,280 veh/day with the data above.

It should be noted that the data spans midnight since there was a constant flow profile from 22:00 – 03:30. This requires two different settings: 0:00 – 03:30 and 22:00 – 24:00. When the data are entered the user always starts at 0:00 and enters the end time for the interval. That end time then becomes the start time for the next interval until data have been entered for the entire 24 h period.

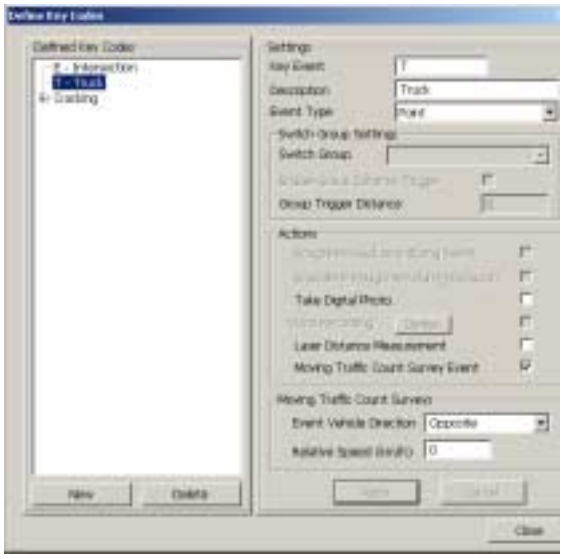
Defining AADT Adjustment Factor

The AADT Adjustment Factor is entered through **Setup|Survey Setup Files| AADT Calibration Factor**. As shown to the right, the user defines a table name. For each month the factor is entered either as a single factor for the entire month or as a daily factor. The **Insert** button adds the records.

13.3 Defining Moving Traffic Count Events and Executing a Survey

Defining Events

It is necessary to assign a keyboard event to be associated with a vehicle. Every time a vehicle travelling in the opposite direction is passed, the appropriate key should be pressed. This is done as described in Section 6.3. The screen to the right is an example of this for a truck.



Executing a Survey

Once the system has been set up with keys assigned to record traffic data, the moving traffic survey is done by having the operator press a key when a vehicle travelling in the opposite direction is passed.

When a key is pressed the time of observation is stored in the data file along with the vehicle class and the key pressed. These data are then used to calculate the AADT.

13.4 Setup Options

Processing Setup options

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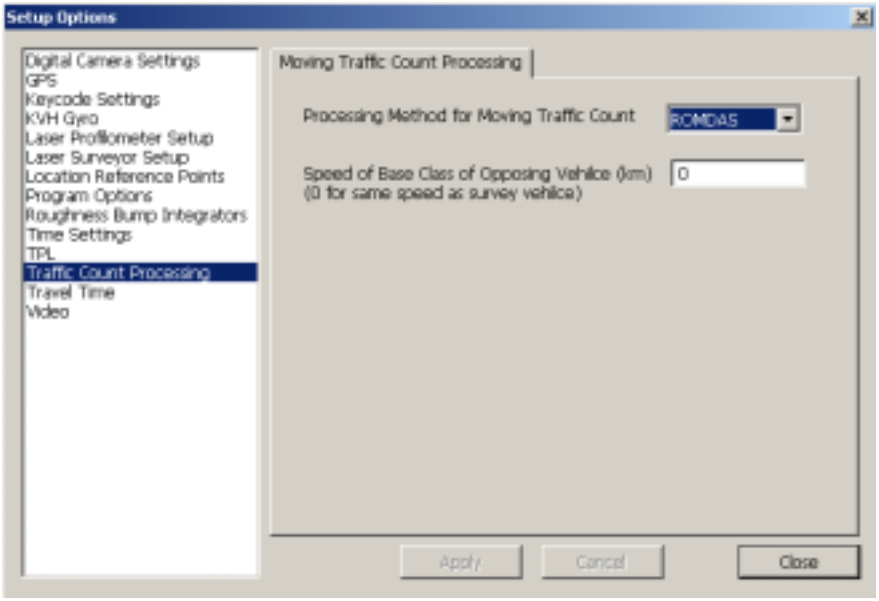

- **Processing Method for Moving Traffic Count:** The ROMDAS method is the default. This uses the relative speed of different vehicles to improve upon the ADT estimate. The TRL method corrects for vehicles overtaking and overtaken.
- **Speed of Opposing Vehicle:** When using the ROMDAS method the speed of the opposing vehicles is important. This is set to 0 as the default which means that the survey vehicle is assumed to travel at the same mean speed as the opposing vehicles.

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14 Travel Time Surveys

14.1 Introduction

Overview

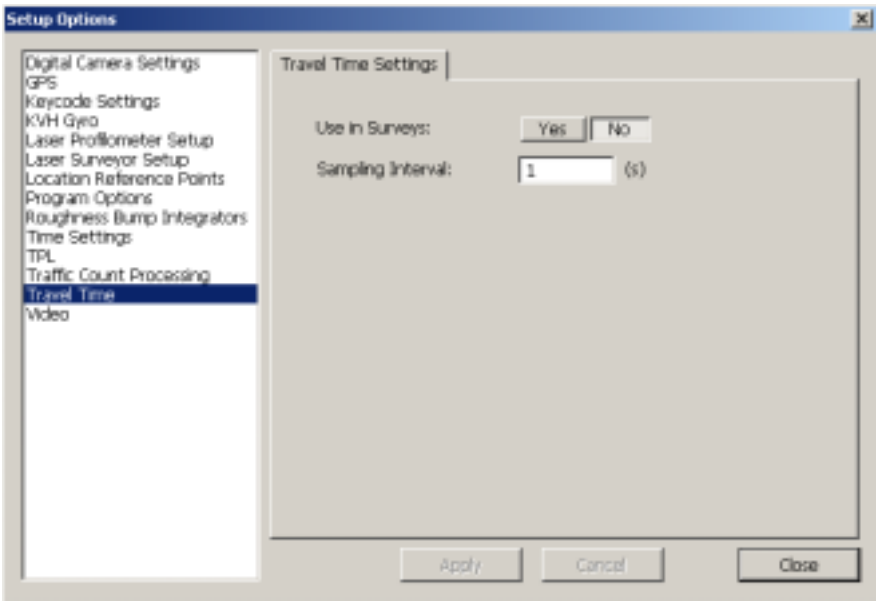
The speed survey option is designed to collect data on travel times and accelerations. It is used for floating car surveys as well as congestion evaluation through the acceleration noise.

The data are collected at user defined intervals (default = 1 s) and consist of the cumulative distance travelled and the cumulative time when the observation was made. The interval can be changed as described in this Section.

In common with roughness surveys, it is recommended that LRPs be used in all speed surveys. This will ensure that data from successive surveys can be correlated with each other. This is particularly important for travel time surveys which are used to evaluate level of service on road networks.

14.2 Setup Options

Setup Options



- **Use in Surveys**: this is defined as the cumulative distance travelled divided by the cumulative time. When LRPs are used the value represents the average speed between LRPs. It is reported in km/h.
- **Sampling Interval**: the instantaneous speed is the speed over the last observation interval. It is the change in distance divided by the change in time. It is reported in km/h.

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14.3 Data Processing

Overview

The time, speed and acceleration profile calculation uses the raw travel time data to calculate the average speed as well as the instantaneous speeds and accelerations:

- **average speed**: this is defined as the cumulative distance travelled divided by the cumulative time. When LRPs are used the value represents the average speed between LRPs. It is reported in km/h.
- **instantaneous speed**: the instantaneous speed is the speed over the last observation interval. It is the change in distance divided by the change in time. It is reported in km/h.
- **instantaneous acceleration**: this is calculated as the change in instantaneous speed divided by the change in time. It is reported in m/s^2.

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15 Digital Odometer

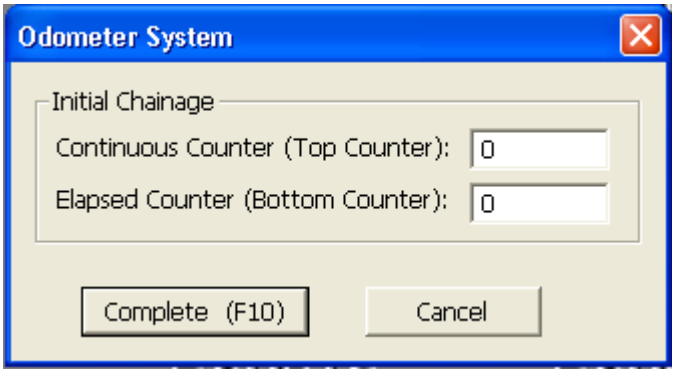
Overview

The ROMDAS **Odometer System** option allows the PC to be used as a digital odometer. It is designed to replicate a dual display trip meter with both a continuous and elapsed distance counters.

Setup

For the top and bottom counters the user can enter two items of data:

- **Initial Chainage**: This is the chainage to start the display at. The values can be entered for the Continuous Distance Counter or the Elapsed Distance Counter.



For example, one may be 1000 m from the beginning of the road and wish to use this as the initial chainage. By setting this value as the initial chainage the display would start at 1000 and increment upwards.

Using the Odometer

When these data have been entered, the **F10** key should be pressed.

The vehicle should be positioned at the start of the section. The user then has the option of pressing the **F1** key to start both distance counters, or the **F2** key to start the Continuous counter only. The screen shot below is an example of the display with both distance counters operating.

The Continous and Elapsed Distance counters are controlled independently. Pressing the **Hold (F10)** key will pause the display of the top Continuous distance counter. However, even though the display is paused the cumulative distance is still being recorded. Thus, pressing the **Hold (F10)** key again will return the display to the current cumulative distance. This is useful for noting the distance of events during a survey.

The bottom counter is used to measure the elapsed distance between two points. Pressing the **SPACE** bar toggles and resets this counter.

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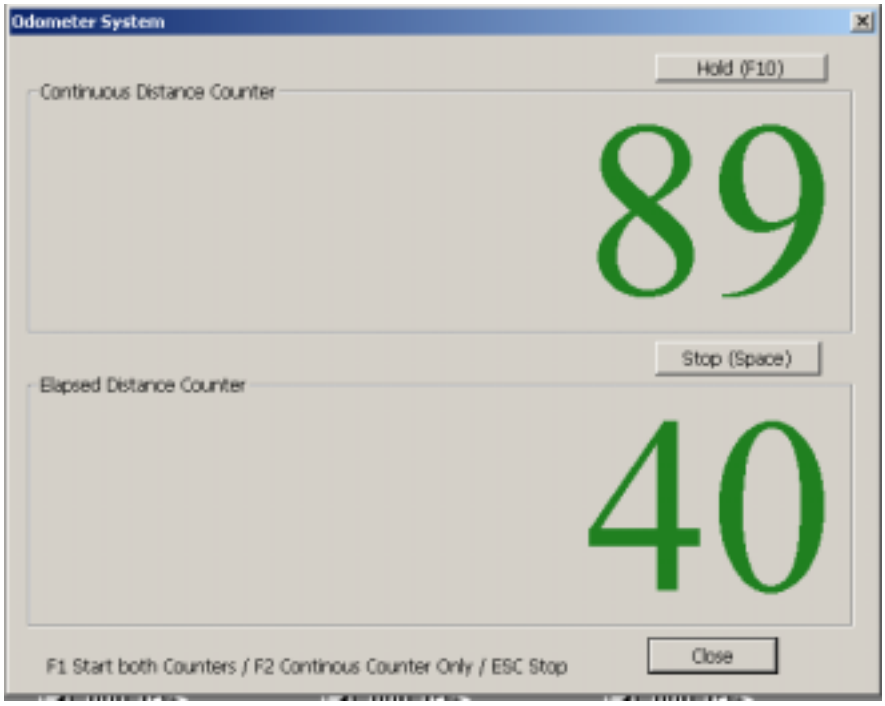

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16 Software Setup Options

16.1 Introduction

Overview

ROMDAS is designed to provide the user with control over most survey settings and options. The defaults are suitable for most situations, but with experience users will modify the settings for their specific needs. They are accessed through the **Setup** entry on the opening menu.

There are two types of settings:

- **Basic Settings** are those which the survey operators typically have access to. They are required for basic setup and operation of ROMDAS.
- **Advanced Settings** are typically set by the survey manager and should not be modified by operators in the field.

Each of these are discussed in the following sections.

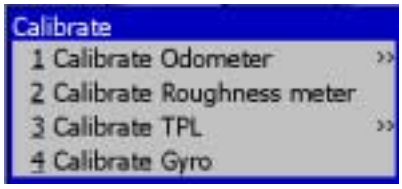
16.2 Basic Settings

Overview

ROMDAS is designed to provide the user with control over most survey settings and options. The defaults are suitable for most situations, but with experience users will modify the settings for their specific needs.

Calibrate

Selecting **Setup|Calibrate** gives the menu to the right. The options are:



- **Calibrate Odometer**. This is used to calibrated the vehicle odometer (see Section 5.2).
- **Calibrate Roughness Meter**. This is used to calibrate the roughness meter (see Section 5.3).
- **Calibrate TPL**. This is used to calibrate the transverse profile logger (see Section 5.4).
- **Calibrate Gyro.** This is used to calibrate the Gyro (see Section 5.6)

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Test Instruments

Selecting **Setup|Test Instruments** gives the menu to the right. The testing of instruments is described in Section 3.14.

Customise

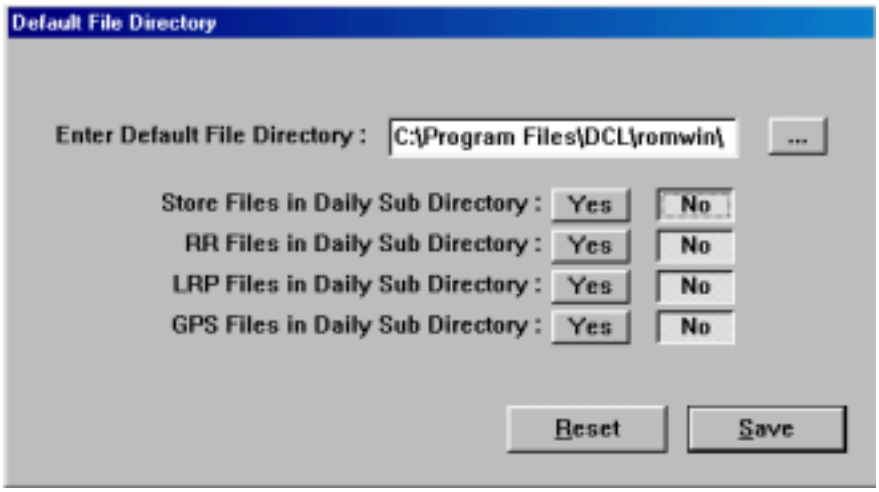
Selecting **Setup|Customise** gives the menu to the right. These options are described in Section 16.2

Default File Directory

From the main menu select:

Setup|Customise|Default File Directory

The window below will be opened where it is possible to define the default file directory.



When the daily sub-directory option is selected the data are stored in subdirectories under the default file directory with a new directory created each day of the survey. The directories have the name YYYYMMDD, where YYYY is the year; MM the month and DD the day. For example, 31 January 2001 would be stored in 20010131 and the first of February 2001 in 20010201.

This option is useful when there are large surveys underway with potentially a large number of files being created. It greatly facilitates data management.

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Define Pause Key

From the main menu select:

Setup|Customise|Define Pause Key

When you wish to pause a survey, by default you press the SPACE bar. However, some users have reported problems with this being accidentally pressed during the survey. This option allows you to assign the pause function to either the F3 or the F6 key. It is recommended that you label the keyboard with which key has the pause function to remind the operator.

Assign Mouse Buttons

From the main menu select:

Setup|Customise|Assign Mouse Buttons

It is possible to use a mouse with ROMDAS. Typically, it is used to replace the need for keyboard entry. The user can assign any keyboard keys to the mouse buttons (one per button). This allows for the operator to hold the mouse and not have to worry about using the keyboard. For example, the ESC key could be assigned to a mouse button and this pushed when passing an LRP.

Colours and Fonts

From the main menu select:

Setup|Customise|Colours and Fonts

This allows for the font type and size to be customised. An example of this is shown below for three different fonts.

User Defined Fields

From the main menu select:

Setup|Customise|User Defined Fields

ROMDAS has a number of 'system' fields that are used for storing data, *eg* Survey_ID for the survey. However, users often need to have additional fields for storing their own data, for example the District that a survey is being conducted in. The data that can be entered are:

- **Field Name**: The name of the field to be displayed
- **Field Type**: The type of data stored (see below)

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Alphanumeric
Any Character
Letters
Numbers

- **Length**: The size of the field

The two sets of screens below show the survey input form without and with user defined fields.

Without User Defined Fields

With User Defined Fields

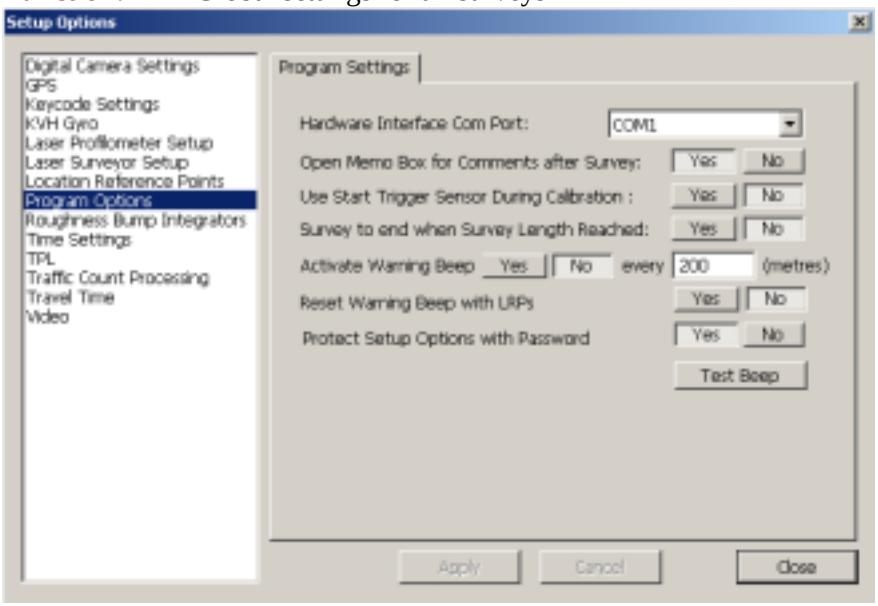
16.3 Advanced Settings

Passwords

If the **Protect Setup Options with Password** option (defined using the **Program Options** setup described later in this section.) has been set Selecting **Setup|Options** from the main menu gives the password entry box shown below: The correct password must be entered to gain access to the **Setup Options.**

Program Settings

Function: Global settings for all surveys



- **Hardware Interface Com Port**: The serial port that is connected to the ROMDAS Hardware Interface
- **Open Memo Box After Survey**. Allows for operator to enter comments at end of survey.
- **Use Start Trigger Sensor During Calibration**. Monitors the reverse line on the hardware interface. If there is a change of state the calibration survey will start or stop.
- **Survey to End When Survey Length Reached**. If the survey length is entered the survey will automatically stop at that length.
- **Activate Warning Beep**. A beep will sound at the end of the interval defined here.
- **Protect Setup Options with Password**. This option enables or resets the password which allows access to the **Setup Options**. When ROMDAS is installed the password is blank and the **Setup Options** is not password protected.

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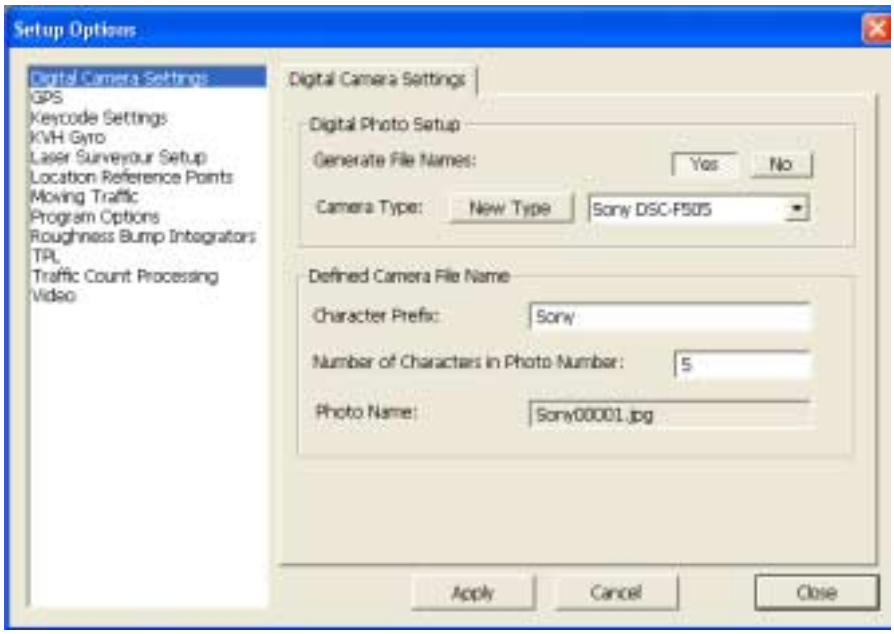
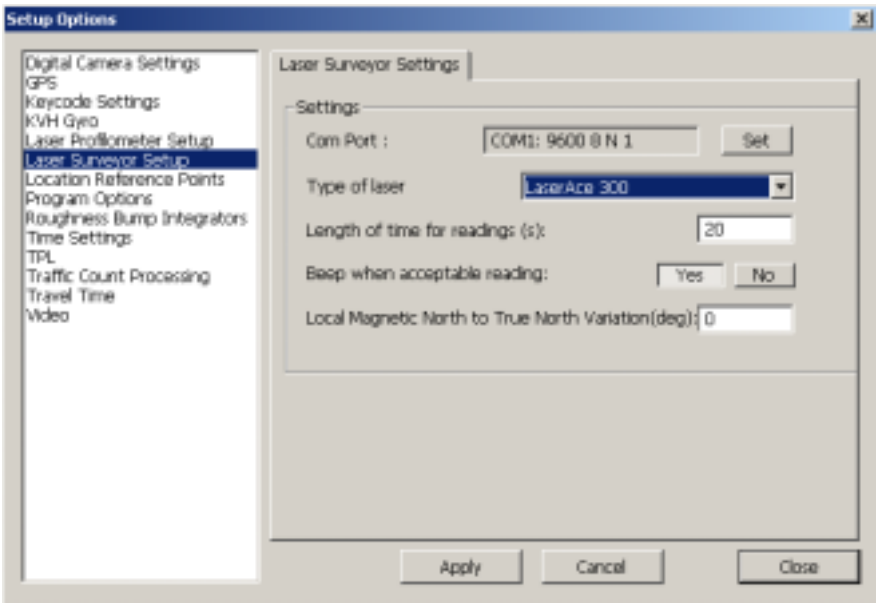
Digital Photos



Laser Surveyor



- **Type of Laser** You must specify the type of laser instrument to be used. Currently only the LaserAce 300 is supported.
- **Length of Time for Readings:** The length of time in seconds for to monitor for readings once the data are received.
- **Beep When Acceptable Reading:** Whether the ROMDAS computer should beep when acceptable Laser reading is received..

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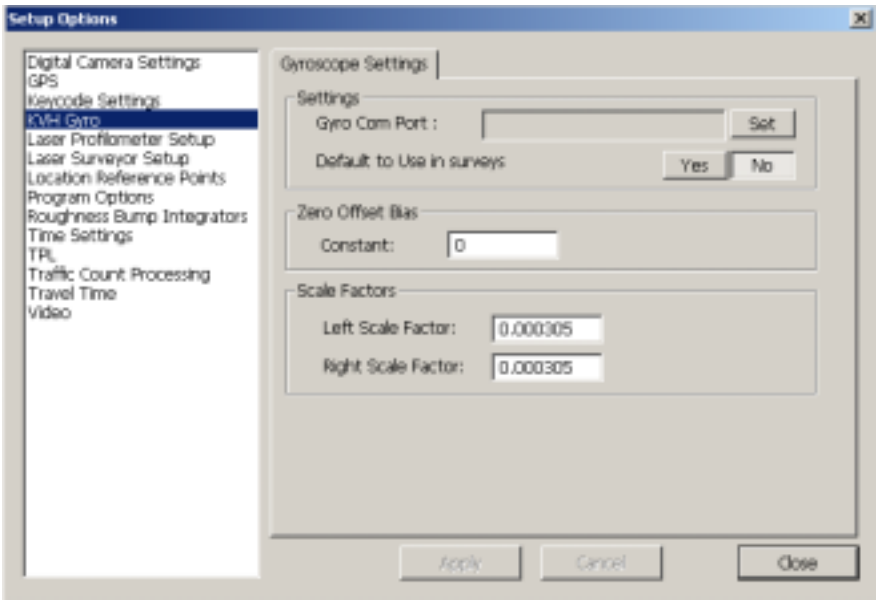
Heading Gyroscope



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17 File Management

17.1 Introduction

Overview

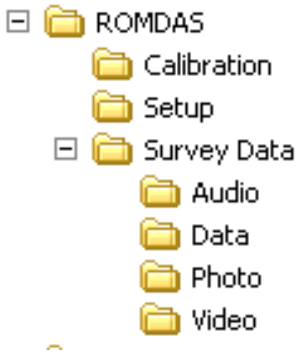
This chapter describes the file structures for the ROMDAS for Windows data. It is divided into the following sections:

- **File Locations**. The locations and types of files saved by ROMDAS.
- **File Structures – Survey Setup and Management Files.** The structures of files used for setting up and managing surveys.
- **File Structures – Survey Raw Data.** The structures of files storing raw survey data.
- **File Structures – Processed Data.** The structures of files containing processed survey data.

17.2 File Locations

Folders

As shown the right, the ROMDAS files are stored in the following folders:



- **Calibration**: Files associated with instrument calibration.
- **Setup**: Files associated with setting up the software.
- **Survey Data**: Files from actual surveys. The survey data are stored in different folders depending upon the type of data: Audio, Data, Photo or Videos.

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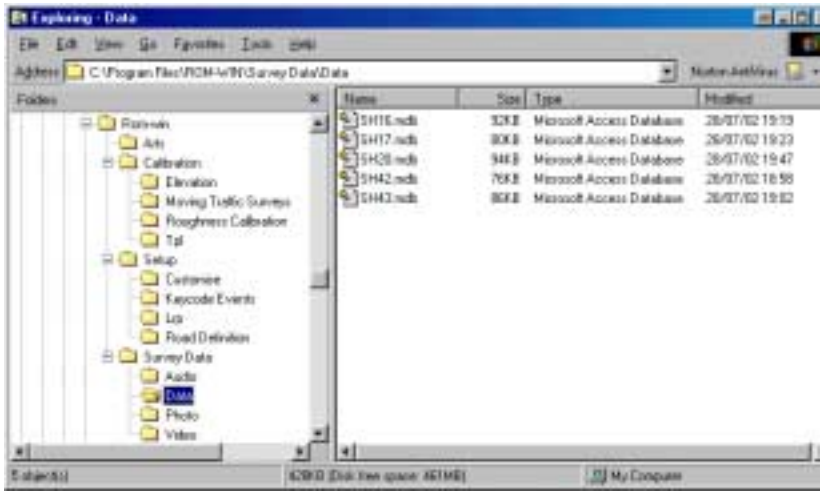
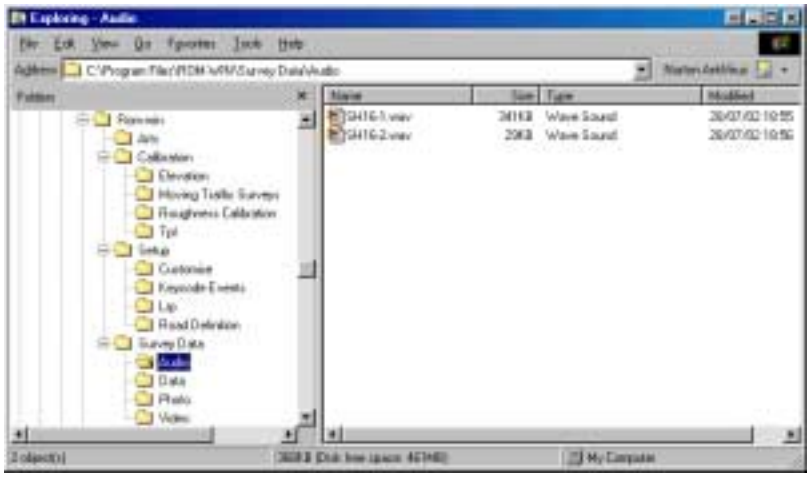
Data Files

All survey data is recorded in a binary format file (rbf). The rbf files can be processed to produce Access .mdb files. The file names are the Survey ID. For example, a Survey ID of SH16 would result in the file SH16.mdb. The various survey exported raw, header and processed information is stored in Access tables within the Access mdb database file.



Audio Files

Internally recorded audio files are stored as Microsoft Wave Sound .wav files. The file names are the Survey ID and the recording number. For example, the first recording for Survey ID of SH16 would result in the file SH16-1.wav; the second SH16-2.wav; *etc*.



17.3 File Structures – Management Files

Overview

Survey management files are files used to for storing survey parameters (*eg* keyboard rating files) or managing survey results.

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- Keycode.mdb — Keycode events
- Road Definition.mdb — Road definition data
- Vehicles.mdb — Odometer calibration data
  Vehicle calibration history
- LRP Master.mdb — LRP Predefinitions
  Copy of all LRP Files
- Survey Logs.mdb — Survey history
- ADT Cal. Factors.mdb — Moving traffic survey ADT factors
- AADT Adj. Factors.mdb — Moving traffic survey AADT factors

Keycode Event

Function: Keyboard rating events
Location: Setup
File Name: Keycode.mdb
Table Name: Keycode

Field Name	Data Type	
EVENT	Text	Key to be Pressed
EVENT_TYPE	Text	Type of Event
EVENT_DESC	Text	Event Description
SWITCH_NAME	Text	Switch Event Name
STOP_BI	Yes/No	Pause Roughness Recording
EQ_BI	Yes/No	Calculate Equivalent Roughness on Roughness Pause
TAKE_PHOTO	Yes/No	Take Digital Photo With Event
LASER_SURV	Yes/No	Use Laser Surveyor
VOICE_REC	Yes/No	Use Voice Recording
TRAFFIC_VEHICLE	Yes/No	Moving Traffic Survey Event
DIRECTION	Number	Direction of Moving Traffic Observation
REL_SPEED	Number	Relative Speed of Moving Traffic Observation
COMMENT	Yes/No	Comment

Odometer Calibration Factors

Function: Stores the odometer calibration factor for each vehicle
Location: Calibration
File Name: Vehicles.mdb
Table Name: Odo_Calibration

Field Name	Data Type	
VEHICLE	Text	Vehicle ID
ODO_Factor	Number	Odometer Calibration Factor
ODO_Date	Date/Time	Date of Odometer Calibration

Vehicle Calibration Log

Function: Records when each vehicle was calibrated
Location: Calibration
File Name: Vehicles.mdb
Table Name: Vehicle

Field Name	Data Type	
VEHICLE	Text	Vehicle ID
ODO_Factor	Number	Odometer Calibration Factor
ODO_Date	Date/Time	Date of Odometer Calibration
Rough_Date	Date/Time	Date of Roughness Calibration
TPL_Date	Date/Time	Date of TPL Calibration

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LRP Pre-Definition

Function: Provides shortcut key for entering LRPs during survey
Location: Setup
File Name: LRP Master.mdb
Table Name: LRP_Def

Field Name	Data Type	
LRP_KEY	Text	LRP Shortcut Key
LRP_DESC	Text	LRP Description

Survey Log

Function: To provide a permanent record of the options and surveys done each day
Location: Survey Data
File Name: Survey Logs.mdb
Table Names: Rlddmmyy (dd=Day; mm=Month; yy=Year)

Field Name	Data Type	
SURVEY_DATE	Date/Time	Survey Date
SURVEY_ID	Text	Survey ID Number
SURVEY_NUMBER	Number	Survey Number
SURVEY_FILE	Text	Survey File Name
LRP_FILE	Text	LRP File Name
SURVEY_DESC	Text	Survey Description
SURVEY_TYPE	Number	Type of Survey
DISTANCE	Number	Distance Travelled
USER_1	Text	User Defined Field - 1
USER_2	Text	User Defined Field - 2
USER_3	Text	User Defined Field - 3
TPL	Yes/No	TPL Used
GPS	Yes/No	GPS Used
GRIP	Yes/No	Griptester Used
VIDEO	Yes/No	Video Used
ROUGH	Yes/No	Roughness Used
LRP	Yes/No	LRPs Used
KEY	Yes/No	Keycode Used
SPEED	Yes/No	Average Survey Speed (km/h)
OPERATOR	Text	Operator Name
VEHICLE	Text	Vehicle ID
COMMENT	Text	Comment

ADT Calibration Factors

Function: To convert moving traffic survey hourly flows to AADT
Location: Calibration
File Name: ADT Calibration Factors.mdb
Table Names: User Defined

Field Name	Data Type	
START_TIME	Text	Start Time (hh:mm)
END_TIME	Text	End Time (hh:mm)
ADT_CORRECT	Number	ADT Correction Factor

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AADT Adjustment Factors

Function: To convert moving traffic survey ADT estimate to an AADT
Location: Calibration
File Name: AADT Adjustment Factors.mdb
Table Names: User Defined

Field Name	Data Type	
MONTH	Text	Month
ALL	Number	AADT Adjustment Factor - All days of week
SUN	Number	AADT Adjustment Factor - Sunday
MON	Number	AADT Adjustment Factor - Monday
TUE	Number	AADT Adjustment Factor - Tuesday
WED	Number	AADT Adjustment Factor - Wednesday
THU	Number	AADT Adjustment Factor - Thursday
FRI	Number	AADT Adjustment Factor - Friday
SAT	Number	AADT Adjustment Factor - Saturday

Laser Elevation Test Header

Function: To record Laser Elevation Test Details
Location: Calibration
File Name: Laser Calibration.mdb
Table Names: Elev_Headers

Field Name	Data Type	
NAME	Text	User Supplied Test Name
LASER	Text	Laser Short Name
DATE_TIME	Date/Time	Date Time
WARM_UP	Number	Warm Up Time (minutes)
NUMBER_BLOCKS	Number	Number of Measurement blocks
NUMBER_READINGS	Number	Number of readings for each Block
DISCARD	Number	Number of readings to discard for each block
TOLERANCE	Number	Pass Tolerance (mm)
BLOCK_SIZE_1	Number	Block Size 1 (mm)
BLOCK_SIZE_2	Number	Block Size 2 (mm)
BLOCK_SIZE_3	Number	Block Size 3 (mm)
BLOCK_SIZE_4	Number	Block Size 4 (mm)
BLOCK_SIZE_5	Number	Block Size 5 (mm)
BLOCK_SIZE_6	Number	Block Size 6 (mm)
BLOCK_SIZE_7	Number	Block Size 7 (mm)
BLOCK_SIZE_8	Number	Block Size 8 (mm)
BLOCK_SIZE_9	Number	Block Size 9 (mm)
BLOCK_SIZE_10	Number	Block Size 10 (mm)

Laser Elevation Test Data

Function: To record Laser Elevation Test Data
Location: Calibration
File Name: Laser Calibration.mdb
Table Names: Elev_Data_*User supplied name*

Field Name	Data Type	
BLOCK_SIZE	Number	Block size (mm)
PACKET_ID	Number	Laser Packet ID
DATA	Number	Laser Elevation measurement (mm)

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Laser Elevation Test Packet Diagnostic Data

Function: To record Laser Elevation Test Packet Data. This table is for DCL diagnostics.
Location: Calibration
File Name: Laser Calibration.mdb
Table Names: Elev_pkt_*User supplied name*

Field Name	Data Type	
PACKET_ID	Number	Laser Packet ID
UNIT_NO	Number	Laser Elevation Unit Number
SEQUENCE	Number	Packet Sequence Number
ODO	Number	Odo
LENGTH	Number	Packet Length
SYNC	Number	Sync Stamp
ERROR_STATUS	Number	Error Status

Laser Bounce Test

Function: To record Laser Bounce Test Data
Location: Calibration
File Name: Laser Calibration.mdb
Table Names: Bounce_Profile_*User supplied name*

Field Name	Data Type
CHAINAGE	Number
ELEVATION	Number
ACCELERATION	Number
PROFILE	Number
FILTERED_ACC	Number
FILTERED_ELV	Number
FILTERED_PROFILE	Number

17.4 File Structures – Raw Data

Overview

The survey raw data are the data recorded in the surveys, before being processed. This includes:

- Header File — Summary of key data
- Road Chainages — Locations where anything was recorded
- Raw Keycode — Raw keyboard rating data
- Raw Roughness — Raw roughness data
- LRP — LRP data

Header File

Function: Records key data for the survey
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: Header_*Survey ID*

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(*eg* Header_SH16)

Field Name	Data Type	
HDR_ID	Number	Header File ID
SURVEY_ID	Text	Survey ID Number
SURVEY_DESC	Text	Survey Description
SURVEY_FILE	Text	Survey File Name
VEHICLE	Text	Vehicle ID
OPERATOR	Text	Operator Name
USER1_NAME	Text	User 1 Field Name
USER_1	Text	User Defined Field - 1
USER2_NAME	Text	User 2 Field Name
USER_2	Text	User Defined Field - 2
USER3_NAME	Text	User 3 Field Name
USER_3	Text	User Defined Field - 3
LRP_FILE	Text	LRP File Name
LRP_RESET	Text	LRP Reset Option
LRP_START	Number	LRP Start Number
LRP_OPTION	Number	LRP Option
CHAIN_INIT	Number	Chainage - Initial
CHAIN_START	Number	Chainage - Start
DIR	Text	Survey Direction
LANE	Number	Lane number
DEVICES	Text	TPL/GPS/Grip Tester/Video Used
INTERVAL	Number	Roughness Sampling Interval
SURVEY_DATE	Date/Time	Survey Date
OTHERSIDE	Yes/No	Other Side Survey
ODIS	Number	Distance for Other Side Survey
ODIS_LSTLRP	Number	Distance from LRP for Other Side Survey
SECT_LEN	Number	Section Length (m)
ODOMETER	Number	Odometer Calibration Factor
VERSION	Text	Software Version

Keyboard Rating

Function: Contains keyboard rating data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: Keycode_Raw_*Survey ID*
(*eg* Keycode_Raw_SH16)

Field Name	Data Type	
CHAINAGE_START	Number	Event Start Chainage (m)
CHAINAGE_END	Number	Event End Chainage (m)
EVENT	Text	Event Key
SWITCH_GROUP	Text	Switch Group Name
EVENT_DESC	Text	Event Description
LRP_CHAINAGE_START	Number	Event Start LRP Chainage (m)
LRP_CHAINAGE_END	Number	Event End LRP Chainage (m)
LRP_NUMBER_START	Number	Start LRP Number
LRP_NUMBER_END	Number	End LRP Number
PHOTO_SET	Number	Photo Set Number
LATITUDE	Number	GPS Latitude (degrees)
LONGITUDE	Number	GPS Longitude (degrees)
ALTITUDE	Number	GPS Altitude (m)
OFFSET	Number	Offset of Event from Road (m)
HEADING	Number	Laser Surveyor Heading (degrees)
HORZ_DIST	Number	Laser Surveyor Horizontal Distance to Event (m)
INCLINE	Number	Laser Surveyor Inclination (degrees)

LRP Files

Function: Contains LRP data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: LRP_*Survey ID*
(*eg* LRP_SH16)

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Field Name	Data Type	
RECTYPE	Number	Record Type
LRP_ID	Text	LRP ID
LRP_NUMBER	Number	LRP Number
LRP_DISPL	Number	LRP Chainage (m)
LRP_DESC	Text	LRP Description
PHOTO_NUM	Number	Photo Number
PHOTO_NAME	Text	Name of Photo File
GPS_TIME	Text	GPS Time Code (s)
LATITUDE	Number	GPS Latitude (decimal degrees)
LONGITUDE	Number	GPS Longitude (decimal degrees)
ALTITUDE	Number	GPS Altitude (m)
OFFSET	Number	Offset of LRP from Road (m)
HORZ_DIST	Number	Laser Surveyor Horizontal Distance to LRP (m)
INCLINE	Number	Laser Surveyor Inclination (degrees)
HEADING	Number	Laser Surveyor Heading (degrees)
HDR_ID	Number	Header File ID
Comment	Text	User Defined Comment

Raw Roughness Data

Function: Contains Roughness data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: Roughness_Raw_*Survey ID*
(*eg* Roughness_Raw_SH16)

Field Name	Data Type	
RECTYPE	Number	Record Type
LRP_ID	Text	LRP ID
LRP_NUMBER	Number	LRP Number
CHAINAGE	Number	Chainage (m)
CUMULATIVE_CHAINAGE	Number	Cumulative Chainage (m)
ROUGH_1	Number	BI-1 Roughness (Counts per Interval)
ROUGH_2	Number	BI-2 Roughness (Counts per Interval)
SPEED	Number	Average Speed over Interval (km/h)
COMMENT	Text	Comment
HDR_ID	Number	Head File ID

GPS Header

Function: Contains GPS header data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: GPS_Header_*Survey ID*
(*eg* GPS_Header_SH16)

Field Name	Data Type	
RECEIVER_TYPE	Text	NMEA or TRIMBLE TSIP
SAMPLING_INTERVAL	Number	GPS Sampling Interval (s)
ANTENNAE_HEIGHT	Number	Height of GPS Antenae above road (m)
OFFSET_DIRECTION	Text	Offset Direction (Left or Right)
OFFSET_DISTANCE	Number	Offset Distance (m)
GENERATED_SSF	Yes/No	PathFinder Office ssf file generated

GPS Data

Function: Contains raw GPS data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: GPS_Raw_*Survey ID*
(*eg* GPS_Raw_SH16)

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Field Name	Data Type	
CHAINAGE	Number	Chainage (m)
TIME	Number	Time (s)
LRP_NUMBER	Number	LRP Number
GPS_TIME	Text	GPS Time (s)
UTC_DATE	Text	UTC Date
LATITUDE	Number	GPS Latitude (decimal degrees)
LONGITUDE	Number	GPS Longitude (decimal degrees)
ALTITUDE	Number	GPS Altitude (m)
HEADING	Number	GPS heading (degrees)
PDOP	Number	PDOP
DGPS	Yes/No	Differential GPS

TPL Data

Function: Contains TPL raw data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: TPL_Raw_*Survey ID*
(*eg* TPL_Raw_SH16)

Field Name	Data Type	
CHAINAGE	Number	
SPEED	Number	
LRP_NUMBER	Number	
ELEV1	Number	Raw uncorrected Elevation
ELEV2	Number	Raw uncorrected Elevation
ELEV3	Number	Raw uncorrected Elevation
ELEV4	Number	Raw uncorrected Elevation
•		
ELEV29	Number	Raw uncorrected Elevation
ELEV30	Number	Raw uncorrected Elevation
ELEV31	Number	Raw uncorrected Elevation

TPL Header

Function: Contains TPL header data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: TPL_Header_*Survey ID*
(*eg* TPL_ Header_SH16)

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Field Name	Data Type	
SURVEY_ID	Text	
CONSTANT	Number	Calibration Coefficient Constant
SLOPE	Number	Calibration Coefficient Slope
STANDARD_DISTANCE	Number	Fixed Target Distance at Standard Conditions
SAMPLING_INTERVAL	Number	TPL Sampling Interval(m)
WINGS	Text	Wing Configuration Used
NODE_TO_CURB	Number	Node number nearest the curb (left or right hand drive)
DIST5-6	Number	Distance between Sensor 5-6 (mm)
DIST10-11	Number	Distance between Sensor 10-11(mm)
DIST15-16	Number	Distance between Sensor 15-16 (mm)
DIST20-21	Number	Distance between Sensor 20-21 (mm)
DIST25-26	Number	Distance between Sensor 25-26 (mm)
CORRECT_DEVIATIONS	Yes/No	Error Corrections-Correct for Deviations
CORRECT_MAX_DEVIATION	Number	Error Corrections-Maximum reading (mm)
CORRECT_MIN_DEVIATION	Number	Error Corrections-Minimum reading (mm)
CORRECT_INC	Yes/No	Error Corrections-Correct Incremental differences
CORRECT_INC_DIFF	Number	Error Corrections-Incremental difference (mm)
CORRECT_ZERO	Yes/No	Error Corrections-Correct Zero Elevations
CORRECT_REPLACE	Yes/No	Error Corrections
EDGE_HIGHPOINT_DISTANCI	Number	Distance From Edge to test for High Point (m)
STRAIGHT_EDGE_LEFT	Number	Left Straight Edge Length (m)
STRAIGHT_EDGE_RIGHT	Number	Right Straight Edge Length (m)
BIAS_CONSTANT_SE	Number	Straight Edge Bias Correction Constant
BIAS_SLOPE_SE	Number	Straight Edge Bias Correction Slope
LOW1_FIRST	Number	Pseudo Rut- First Sensor to look for low point 1
LOW1_LAST	Number	Pseudo Rut- Last Sensor to look for low point 1
HIGH_FIRST	Number	Pseudo Rut- First Sensor to look for high point
HIGH_LAST	Number	Pseudo Rut- Last Sensor to look for high point
LOW2_FIRST	Number	Pseudo Rut- First Sensor to look for low point 2
LOW2_LAST	Number	Pseudo Rut- Last Sensor to look for low point 2
BIAS_CONSTANT_PS	Number	Pseudo Rut Bias Correction Constant
BIAS_SLOPE_PS	Number	Pseudo Rut Bias Correction Slope
DATUM_ELEV_1	Number	Datum Level (mm)
DATUM_ELEV_2	Number	Datum Level (mm)
•		
DATUM_ELEV_29	Number	Datum Level (mm)
DATUM_ELEV_30	Number	Datum Level (mm)

17.5 File Structures – Processed Data

Overview

GPS Processed Data

Function: Contains processed GPS data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: GPS_Processed_*Survey ID*
(*eg* GPS_Processed_SH16)

Field Name	Data Type	
GPS_Time	Date/Time	
Latitude	Number	GPS Latitude (decimal degrees)
Longitude	Number	GPS Longitude (decimal degrees)
Northing	Number	GPS Northing (meters)
Easting	Number	GPS Easting (meters)
Alt_HAE	Number	GPS Altitude Height Above Elipsiod (m)
Alt_MSL	Number	GPS Altitude Mean Sea Level (m)
Heading	Number	GPS heading (degrees)
Track	Number	Gyro heading (degrees)
PDOP	Number	PDOP
DGPSUsed	Yes/No	Diferential GPS
GPS_Source	Number	GPS Source (1-reciever, 2-DGPS,5- Gyro)

Roughness Processed Data

Function: Contains processed Roughness BI data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: Roughness_Processed_*Survey ID*
(*eg* Roughness_ Processed_SH16)

Field Name	Data Type	
CHAINAGE	Number	Cumulative Chainage (m)
LRP_FROM	Number	LRP Chainage of start of Roughness Interval (m)
LRP_TO	Number	LRP Chainage of end of Roughness Interval (m)
LRP_NUMBER	Number	LRP Number
SPEED	Number	Average Speed over Interval (km/h)
RAW_C_1	Number	Raw Count BI1
RAW_C_2	Number	Raw Count BI2
RAW_C_1_KM	Number	Raw Countper Km BI1
RAW_C_2_KM	Number	Raw Countper Km BI2
C_ROUGH_1	Number	Calibrated Roughness BI1
C_ROUGH_2	Number	Calibrated Roughness BI2
CALIB_RGH	Number	Calibrated Roughness average both BI's
QUALITY	Number	Percentage of BI readings vs Equivelent roughness
C_1_A1	Number	Calibration Factor A1 applied for BI1
C_1_A2	Number	Calibration Factor A2 applied for BI1
C_1_A3	Number	Calibration Factor A3 applied for BI1
C_1_A4	Number	Calibration Factor A4 applied for BI1
C_1_A5	Number	Calibration Factor A5 applied for BI1
C_1_A6	Number	Calibration Factor A6 applied for BI1
C_1_A7	Number	Calibration Factor A7 applied for BI1
C_2_A1	Number	Calibration Factor A1 applied for BI2
C_2_A2	Number	Calibration Factor A2 applied for BI2
C_2_A3	Number	Calibration Factor A3 applied for BI2
C_2_A4	Number	Calibration Factor A4 applied for BI2
C_2_A5	Number	Calibration Factor A5 applied for BI2
C_2_A6	Number	Calibration Factor A6 applied for BI2
C_2_A7	Number	Calibration Factor A7 applied for BI2

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TPL Processed Data

Function: Contains processed TPL data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: TPL_Processed_*Survey ID*
(*eg* TPL_ Processed_SH16)

Field Name	Data Type	
DESCRIPTION	Text	
CHAINAGE	Number	
SPEED	Number	
LRP_NUMBER	Number	
LRP_CHAINAGE	Number	
ELEV1	Number	Corrected Sensor value (mm)
ELEV2	Number	Corrected Sensor value (mm)
ELEV3	Number	Corrected Sensor value (mm)
ELEV4	Number	Corrected Sensor value (mm)

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ELEV29	Number	Corrected Sensor value (mm)
ELEV30	Number	Corrected Sensor value (mm)
ELEV31	Number	Corrected Temparature Sensor value
EDGE_UPLIFT	Number	
EDGE_DISPL	Number	
CNTR_UPLIFT	Number	
CNTR_DISPL	Number	
RUT_EDGE_SE	Number	Straight Edge - Rut Depth - curb edge (mm)
RUT_CNTR_SE	Number	Straight Edge - Rut Depth - centre (mm)
RUT_SE	Number	Straight Edge - Rut Depth (mm)
RUT_EDGE_PS	Number	Psuedo Rut- Rut Depth - curb edge (mm)
RUT_CNTR_PS	Number	Psuedo Rut- Rut Depth - centre (mm)
RUT_PS	Number	Psuedo Rut- Rut Depth (mm)
CRCTD_RUT_EDGE_SE	Number	Corrected Straight Edge - Rut Depth - curb edge (mm)
CRCTD_RUT_CNTR_SE	Number	Corrected Straight Edge - Rut Depth - centre (mm)
CRCTD_RUT_SE	Number	Corrected Straight Edge - Rut Depth (mm)
CRCTD_RUT_EDGE_PS	Number	Corrected Psuedo Rut- Rut Depth - curb edge (mm)
CRCTD_RUT_CNTR_PS	Number	Corrected Psuedo Rut- Rut Depth - centre (mm)
CRCTD_RUT_PS	Number	Corrected Psuedo Rut- Rut Depth (mm)
SE_EDGE_HIGH1	Number	Straight Edge - curb edge High Point sensor
SE_EDGE_LOW	Number	Straight Edge - curb edge Low Point sensor
SE_EDGE_HIGH2	Number	Straight Edge - curb edge High Point sensor
SE_CNTR_HIGH1	Number	Straight Edge - centre High Point sensor
SE_CNTR_LOW	Number	Straight Edge - centre Low Point sensor
SE_CNTR_HIGH2	Number	Straight Edge - centre High Point sensor
PS_HIGH_1	Number	Psuedo Rut - High Point sensor
PS_LOW	Number	Psuedo Rut - Low Point sensor
PS_HIGH_2	Number	Psuedo Rut - High Point sensor

Laser Profiler Processed Data

Function: Contains processed Laser Profiler data
Location: Survey Data|Data
File Name: *Survey ID*.mdb (*eg* SH16.mdb)
Table Names: Plaser_IRI_*Survey ID*
(*eg* Plaser_IRI_SH16)

Field Name	Data Type	
CHAINAGE	Number	Cumlative Chainage (m)
LRP_FROM	Number	LRP Chainage of start of Roughness Interval (m)
LRP_TO	Number	LRP Chainage of end of Roughness Interval (m)
LRP_NUMBER	Number	LRP Number
SPEED	Number	Average Speed over Interval (km/h)
LWP_IRI	Number	shortname IRI (mm/km)
LWP_QUALITY	Number	shortname Quality (percent)
RWP_IRI	Number	shortname IRI (mm/km)
RWP_QUALITY	Number	shortname Quality (percent)

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Language

LICENSEE agrees that this agreement be drafted in the English language.

Governing Law

This Agreement shall be governed and be construed in accordance with the laws of New Zealand.

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Appendix A: Installing the Speed/Distance Sensor

Sensor Options 173
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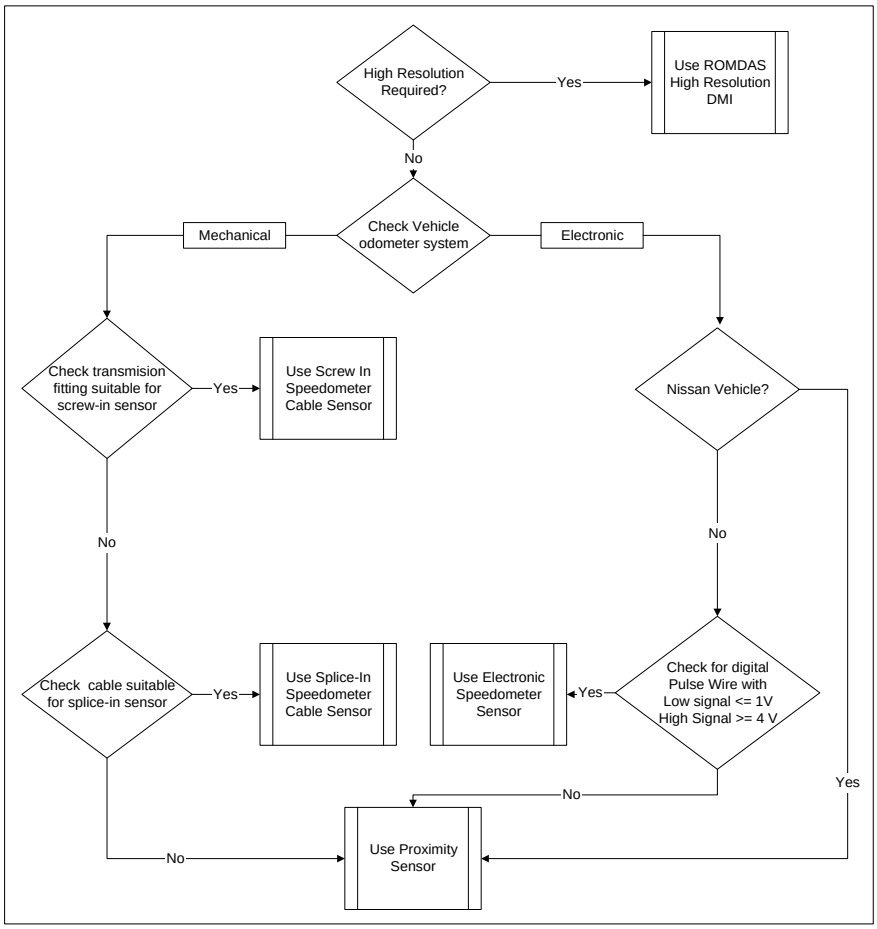
Sensor Options

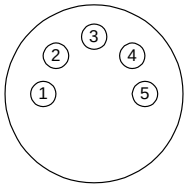
The following are the odometer sensor options available with ROMDAS:

- **Screw-in transmission sensors** – these screw directly onto vehicle transmission speedometer cable fitting where the fitting external thread size is either M20x1.5 (Japanese) or M18 x1.5 (European). It works with most vehicles with mechanically driven speedometer cable.
- **Splice-in cable** for cable driven speedometer vehicles where screw-in sensor does not fit.
- **Electronic sensor** for most vehicles with electronic pulse driven electronic speedometers where Low signal is <= 1 Volt and High signal >= 4 Volts.
- **Proximity sensors** which are affixed to the inside of the wheel and monitor when the hub rotates. These are used when one of the first three sensors (or the high resolution DMI) is unsuitable.
- **High Resolution DMI** which is mounted to the wheel and is used for highly accurate measurements



Decision Tree For Sensor Selection

The odometer sensor connects to the ROMDAS hardware interface using a 3 or 5 pin DIN plug. The figure to the right shows the pin numbering for the 5 pin plug (the three pin only has pins 1-3-5). **NOTE:** This layout is when looking at the back of the DIN plug. As shown in the table below, the wire colours vary depending upon the sensor type.



	Pin 1	**Pin 3**	**Pin 5**
	+5 v Power	*Earth*	*Signal*
Screw-in Transmission	Blue	Unshielded	White/Blue
Splice-in Cable	Red	Black	White
Electronic	Red	Black	White
Proximity	Red	Black	Green
HRDMI	Red	Black	Blue

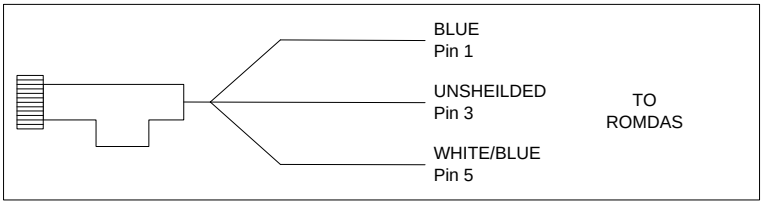
Screw-in Transmission Sensor

The transmission screw-in sensor is used for speedometer cable equipped vehicles. The photos below are examples of these sensors.

The sensor will fit most modern Japanese and European vehicles with cable driven sensors. Installation is as follows:

1. Unscrew the speedometer cable from the transmission. The end of the cable should have a flattened side which is the same size as the drive pin.
2. Connect the speedometer cable to the sensor and tighten. The flattened side of the cable should fit into the notch in the end of the sensor.
3. Check the cable and sensor turn freely by turning the drive pin.
4. Check the location of the notch in the transmission where the drive pin will be inserted. Rotate the drive pin so that it is correctly aligned.
5. Connect the sensor to the gearbox.
6. Connect the sensor plug to the 5 pin ROMDAS DIN cable.

The figures below show the wiring diagrams for the sensors.



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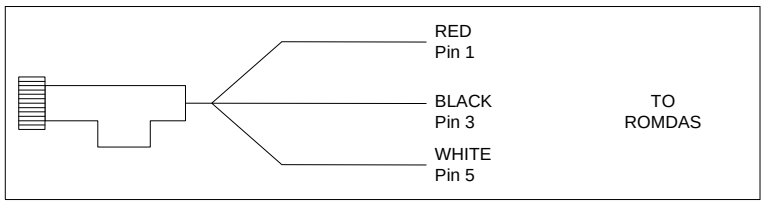
Wiring Connections for Screw-in Sensor

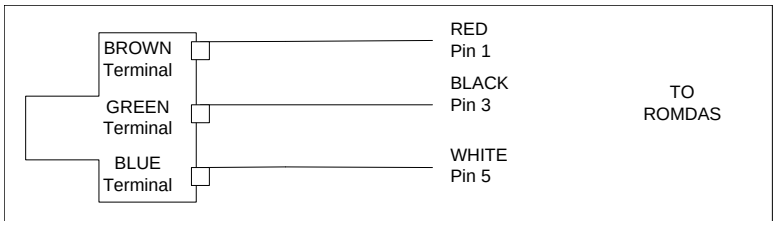


Wiring Connections for pre 2000 Screw-in Sensor

Splice-in Speedometer Cable Sensor

This sensor is used for vehicles which have a gearbox which is incompatible with the screw-in sensor. The Sensor has three blades permanently affixed to it. A short cable with terminal connectors is affixed to the blades. This cable is then connected to the ROMDAS interface via an odometer extension cable.

The figure below shows the wiring connections for this sensor.



Wiring Connections for Splice-in Sensor

Installation is done by removing the cable from the cable housing and splicing in the sensor. The figure below shows how this is done.

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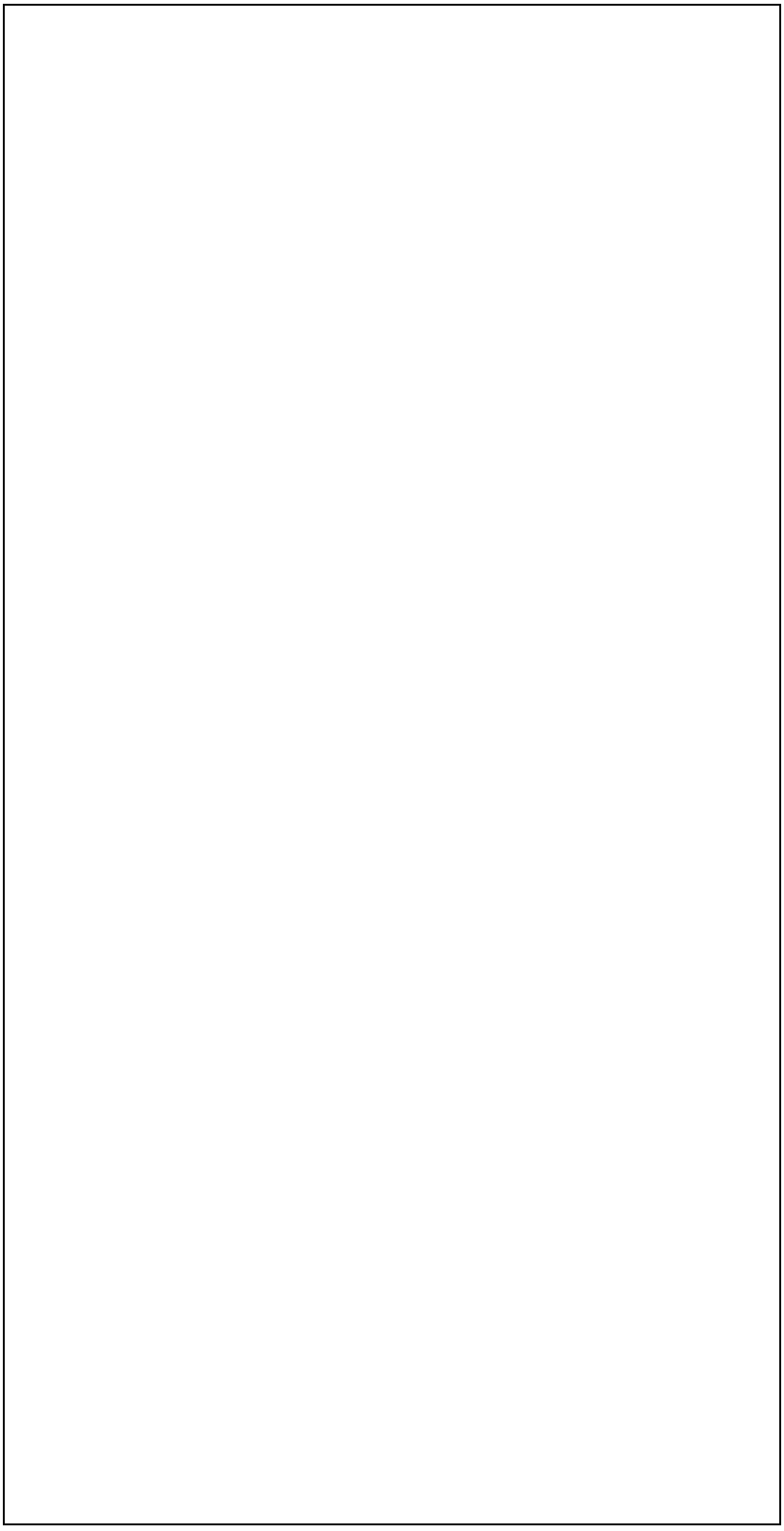

Electronic Sensor

The electronic sensor interfaces with digital pulse sources found on vehicles with digitally pulsed electronic speedometers. The sensor will

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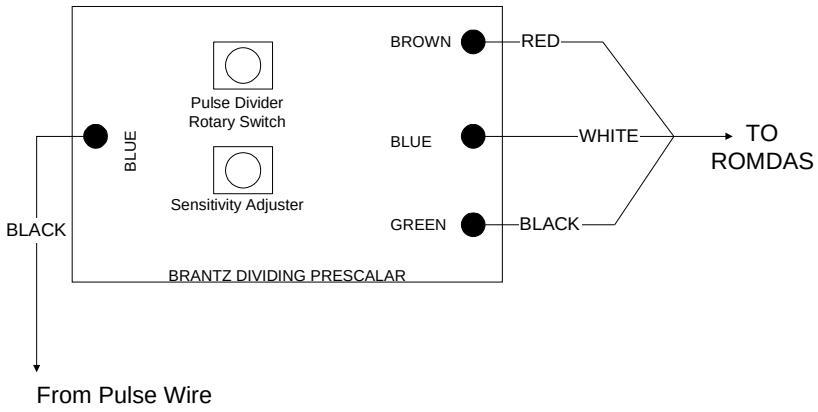
respond to digital earth pulses coming from the vehilces transmission. The low signal is <= 1Volt and high signal is >= 4 Volts. Analog sources are not suitable. Other specifications are:

- Current consumption <10mA
- Drain on vehicles Sensor < 0.5 mA
- Power Source 5V

Installation is as follows:

1. Disconnect the vehicle's electronic speedometer sensor from the gearbox.
2. It is necessary to locate the 'pulse' wire in the loom which feeds the sensor.
3. To do this, leave the sensor wired up and have the vehicle's ignition switch 'ON'.
4. Connect a voltmeter between each wire and ground, then rotate the sensor (i.e move the vehicle drive wheel). The voltmeter will register as follows for each of the wires in the vehicle:
   (a) Supply : Voltmeter reads volts constantly (probably 12 volts)
   (b) Ground: Voltmeter reads '0' volts constantly
   (c) Pulse : Voltmeter 'pulses' between a voltage and '0' as sensor is turned.
5. Once the 'pulse' wire has been located, simply run a wire off this 'pulse' wire and connect it to the **black** wire electronic sensor. The connection is made in parallel so all the original sensor connections remain.
6. Fit the sensor in a convenient place under the dashboard.

If the sensor does not operate correctly, the sensitivity should be adjusted using the adjustment pot. This is located on the sensor board as shown below.



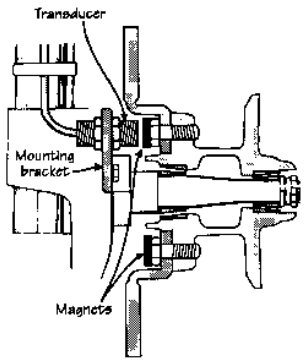
Wiring Diagram for Brantz Electronic Meter

Proximity Sensor

The proximity sensor is mounted on the vehicle and magnets are affixed to the wheel or the inside of the wheel hub. As the wheel turns the

magnets provide a 'Hall Effect' connection which sends pulses to the ROMDAS interface.

Mounting the sensor is different for every vehicle, and requires some imagination. The proximity sensor works best when mounted on a non-driven wheel (rear wheel for front drive cars, front wheel for rear drive cars). If your car is equipped with disk brakes, the back side of the dust shield makes an excellent mount (see right).



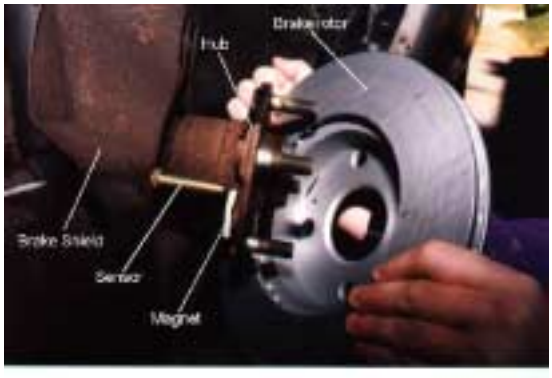
If the vehicle is equipped with drum brakes, you may need to build a small bracket to hold the sending unit close enough to the wheel to sense the magnets. In either case the sensor should be mounted at the highest possible location to minimise its chances of being hit by a rock kicked up from the wheel. The sensor may also be attached to a strut or any other part of the vehicle that maintains its distance from the rotating wheel.

For maximum protection of the sensor, the magnets may be mounted inside the drum, or on the back of the wheel mount studs. The sensor would be mounted directly to the brake assembly, where it is shielded from rocks and other road debris.

A possible alternative to wheel mounting would be mounting the magnets to the vehicle's drive shaft and the sensor to either the transmission or axle casing.

The magnets are mounted to the wheel or hub with the paint mark facing toward the sending unit. Any magnets may be used, but they must be oriented with the south pole of the magnet facing the sending unit. Ceramic magnets of average power should have a gap of about 3 mm between the sensor and the magnet. More powerful "rare earth" magnets may be used which in some cases allow gaps up to 12 mm. It is recommended that you mount the magnets using a **Silicone adhesive** which remains flexible when cured. Epoxy, super-glues, and other bonding agents which become hard or brittle will not stand up well to extended use.

The photo to the right shows a typical installation for a disk brake vehicle. The sensor has been mounted through the rear brake shield, and tightened to be held in place. The magnet is mounted to the rear of the hub with a gap between the end of the sensor and the magnet.



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The photo to the right shows an installation where it is not possible to use the brake shield. A bracket has been made which attaches the sensor to the strut. The magnets are mounted to the hub shaft.

The photo to the right shows a typical installation to a drive shaft or axle. The magnets must be mounted at a point where they will not move relative to the sensor. This mounting works well on all wheel drive vehicles in the front or back, using either the inner or outer CV joint.

For all installations be careful to protect the wires attached to the sensor. The best way to route the wires from the wheel is to attach them to the brake hydraulic line with nylon cable ties (see photo to the right). The brake line is usually routed such that it will not be stressed as the suspension does its job, and also is least prone to breakage from road hazards.

The wire should enter the inside of the car at the earliest possible point, and care should be taken to be sure that it is not crimped at the point of entry. The length of all wires associated with the sending units should be kept as short as possible and should not be routed near ANY ignition components.

High Resolution DMI

The ROMDAS high resolution DMI sensor (HRDMI) has been developed for applications where high distance accuracy is required or where the other sensors (*eg* the electronic sensor) cannot be readily fitted or made to work. The sensor returns 360 pulses per wheel revolution, giving a typical

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distance of 0.007 m per pulse, or over 150,000 pulses per km. By comparison, the standard sensors only give 2,000 - 5,000 pules per km, depending upon the vehicle's equipment.

The HRDMI components are shown in the following photo. The components numbered in this figure are:

1	Encoder Cable Plug
2	Ball Swivel joint
3	Vehicle Wheel-rim Rod Mount and self tapping mounting bolts
4	Extension Rod
5	Stabilisation Rod
6	2 x Stabilisation Rod Nuts and spring washer
7	Stabilisation Rod Joiner
8	Wheelplate
9	Wheel Nut Extenders
10	Wheel Nut Extender to Wheelplate - Retaining Bolts and Washers
11	Encoder shaft collar to Wheelplate - Retaining Bolt and washers
12	Shaft Collar
13	Shaft Collar Grub Screw
14	Allen Key – 3mm for grub screw
15	Encoder with rod mount angle bracket and Rod pivot installed

Installation of the HRDMI is as follows:

1. The encoder should be supplied with shaft collar, rod pivot and encoder rod mount angle bracket already installed as below.

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2. Bolt the encoder shaft collar to the wheelplate. Place locktite onto the wheelplate bolt. Ensure that the fit is flush and the wheelplate rotates without wobbling.

3. The HR DMI is to be installed on a rear wheel of the vehicle preferably on the curb-side of the vehicle.
4. Replace three of the existing wheel nuts with the wheel nut extenders.
5. Attach the wheel plate to the wheel nut extenders with the three retaining bolts and washers. You will need to rotate the wheelplate so that the holes line up with the wheel nut extender holes. The slots in the wheelplate has been designed so that it will fit almost any wheel nut configuration and effectively be self-centring. Should this not be the case it will be necessary to cut additional slots into the wheelplate to match your wheel nut configuration. The centre of the wheelplate must be located in the centre of the wheel.
6. The encoder will now rotate freely so it is necessary to stabilise it in one place. This is done using the stabilisation rod. The rod is attached to the rod pivot on the encoder rod mount angle bracket at one end. The other end of the rod slides through the vehicle wheel-rim rod mount so as to allow for vehicle suspension movement.

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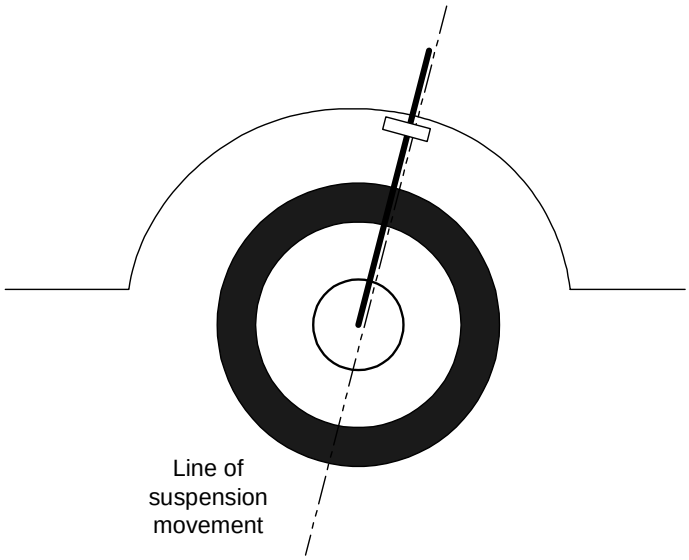
7. Fit a nut to one end of a stabilisation rod and screw to the end of the thread. Insert the end of the stabilisation rod with the nut and a locking spring washer into the threaded hole in the rod pivot on the right angle bracket. Tighten the lock nut so that the stabilisation rod is held in place tightly.

8. The wheel-rim rod mount should be screwed to the vehicle wheel-rim. Holes will need to be drilled into the rim. The wheel-rim rod mount should be positioned so that the stabilisation rod will be in line with the suspension movement, otherwise extra pulses will be generated unrelated to forward movement of the vehicle when the suspension moves up and down. This can generally be done by positioning the vehicle rod mount so that the stabilisation rod and the vehicle shock absorber are in line.



Alignment of suspension and stabilisation rod

9. There are three sets of mounting holes in the wheel-rim mount.

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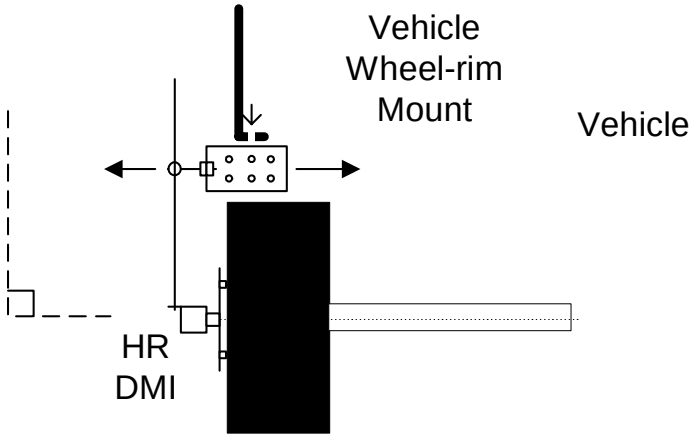
The wheel-rim mount should be positioned so that there is enough adjustment on the ball swivel joint thread to ensure that the stabilisation rod is as close as possible to a 90 degree angle to the encoder shaft.



10. Insert the other end of the stabilisation rod through the ball swivel joint. Fit another nut to the end of the stabilisation rod that has been passed through the ball swivel joint and tighten. This will help to prevent losing any components should something become loose or break.
11. Attach the ball swivel joint to the wheel-rim rod mount. If the rod is too short (make sure you allow for plenty of suspension movement), it can be extended using the rod joiner and the extension rod. The short extension rod should be installed onto the encoder rod mount (step 5) and the longer stabilisation rod on top so that the rod join will be well away from the ball swivel joint.
12. Adjust the ball swivel joint so that the stabilisation rod is at approximately 90 degrees to the encoder shaft when looking forward along the line of the vehicle.
13. Run the encoder cable along the rod and tie it loosely in place. This should be connected to the ROMDAS Interface either directly or through an odometer extension cable. Once installed the final system will be as shown in the following photo.

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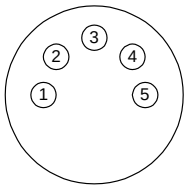
14. Check all bolts and the shaft collar grub nut are tight before testing. You will need a 5mm Allen Key to tighten the grub screw.

The wiring of the DIN plug on the end of the yellow encoder cable is as follows:

Pin 1 -	Red	+5 v Power
Pin 3 -	Blue	Earth
Pin 5 -	Black	Signal

These pin numbers are based at looking at the socket as shown below (note: this shows the layout looking from the back of the DIN plug)



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Appendix B: Installing and Calibrating Roughness Meters

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Installing the Bump Integrator

Components

The ROMDAS Bump Integrator (BI) is illustrated below. It is installed in the rear of the vehicle but is small enough to be relatively unobtrusive.

ROMDAS BI and Mounting Plate

ROMDAS BI Installed in Vehicle With Protective Cover Off

The BI has the following components:

- 1 x Bump integrator
- 1x Base plate and cover

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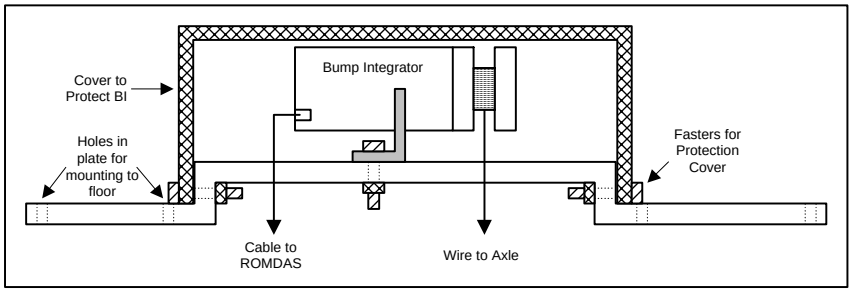
- 1 x BI wire
- 1 x BI hook
- 4 x Self-tapping screws for mounting base plate to vehicle floor
- 2 x Bolts for connecting BI to base plate

Installation Overview

The BI comes with an installation kit consisting of a base plate and a protective cover. The base plate is attached to the floor of the vehicle via screws or bolts (not supplied). The BI is then mounted to the base plate. The cable and the BI wire are fed through holes in the base plate and the protective cover is then fitted. The figure below shows a cross-section of the BI with the protective cover in place.



Cross-section of ROMDAS BI When Installed

When using dual BI's it is **VITAL** that you confirm which is returning data to the BI-1 connection. This is best done by installing the dual BI system and then disconnecting one of the BI units. Connect the ROMDAS simulator to the ODO connection on ROMDAS and start a roughness survey with BI-1 connected. The data displayed should be the left of the two numbers and this corresponds to the left hand wheelpath when driving along the road.

Mounting Options

As shown in below there are several options for installing the BI in a vehicle:

- **Solid Rear Axle**. If the vehicle has a solid rear axle it should be installed over the centre of the differential. This will measure what is termed a 'Half-Car' roughness.
- **Independent Rear Suspension - 2 BI Units**. If there is an independent rear suspension it is recommended that two BI units be installed: one for each wheelpath. Each of these will measure a 'Quarter-Car'. The average of these two will give the overall roughness.
- **Independent Rear Suspension - 1 BI Unit**. The use of 1 BI unit with an independent rear suspension is possible, but not recommended. This is because the vehicle will still measure a 'Quarter-Car' but the roughness measurements will be dominated by the roughness in the single wheelpath—it does not matter which one—being monitored. It will prove difficult to have a good calibration of the meter because the roughnesses will vary between

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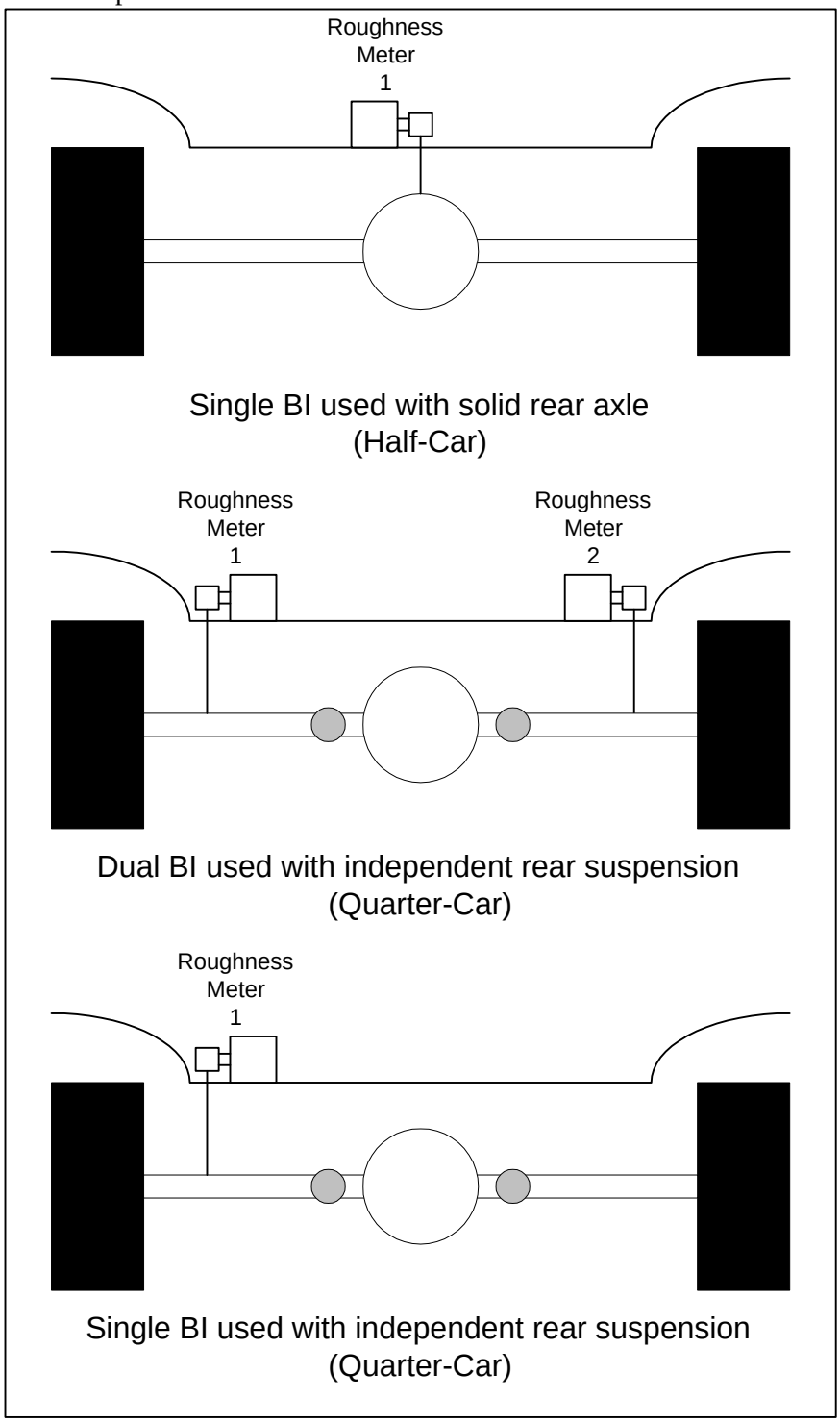
wheelpaths and between test sections.



Installation Options For BI

The fixing point for the BI should always be along the centreline of the axle. If there is an independent rear suspension it should be along the line of the drive shafts. When mounting with a solid rear axle the fixing point should be along the vehicle centreline (see below). With an independent rear suspension the fixing point will depend upon the suspension design and geometry. It is important that if dual BI units are used the fixing

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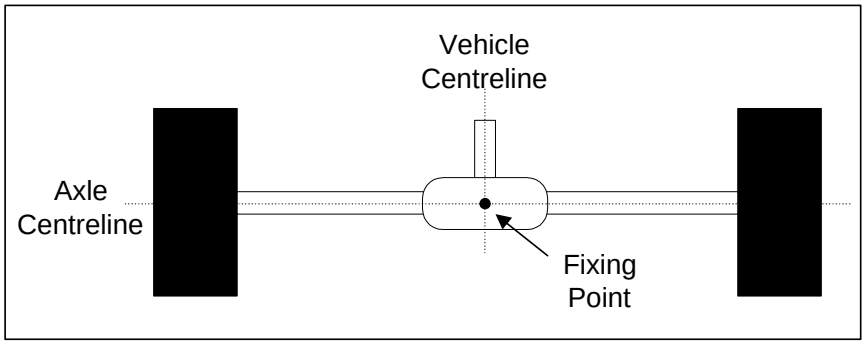
points should be in identical locations.

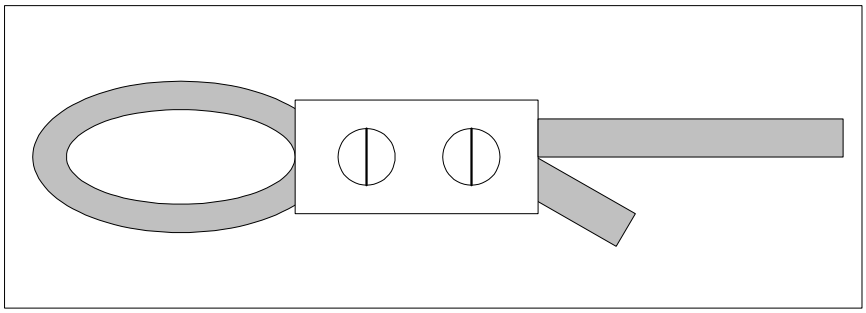


Location of Fixing Point

BI Hook

The BI is usually fixed to the vehicle via a cable and wire hook, although other options than the hook can be used: all that is required is that the wire be firmly fixed to the suspension. Modifications may be required with independent rear suspensions where there is not a good location for installing the hook. The hook should be installed in the appropriate location and bent so that it will hold the end of the wire.

The wire should be threaded through the supplied connector to form a loop as shown below. These connectors are readily available from most electrical suppliers: they are used in 'Fuse Blocks'. The loop must be tight so that there is no flex in the cable.



Looped Wire

A metal plate is supplied with a rod welded to the plate. This should be attached to the differential and the rod bent into a 'hook'. Alternatively, if two BI units are to be used or there is an independent suspension, it should be mounted on the side of the axle.

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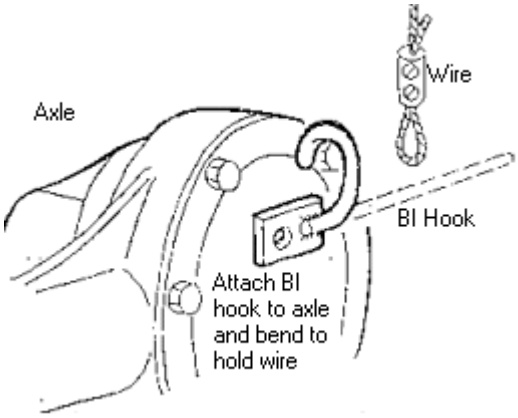

Hook on Side of Axle (2 x BI)

Hook on Centre of Differential

Connecting the Wire

Connecting the wire requires two people.

1. The BI contains a spring which is pre-tensioned by winding it **COUNTERCLOCKWISE IN THE DIRECTION OF THE ARROW** a **MAXIMUM** of 1.5 revolutions. **DO NOT OVERTIGHTEN.**
2. Loop the wire around the BI spindle so that it is of the correct length to connect to the hook.
3. Holding the BI spindle in place, lower the wire through the hole in the floor.
4. Loosen the two screws and loop the wire over the hook.
5. Pull the wire tight and then tighten the two screws.
6. Release the spindle and the wire should tighten (see photo to right).

Check the connection by bouncing the rear bumper on the vehicle. The spindle should move as the vehicle bounces up and down.

BI Wire Connected to Hook

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Replacing the BI Spring

Overview

It is sometimes necessary to replace the BI spring. This section describes how this is done.

NOTE: It is recommended that a spare BI spring be available at all times.

Removing the BI Wire

Firstly, you will need to remove or secure the Bump Integrator Wire attached to the Bump Integrator Unit. Either secure the wire around the spindle with a rubber band or similar or remove the wire as follows:

Unscrew the two retaining screws that hold the wire clamp at the end of wire(where the wire is looped) to be able to pull the BI wire fully off the Bump Integrator spindle (see below).

Calibration Requirements

- Remove the spindle nut in the middle of the Bump Integrator Spindle as shown below using a 13mm socket spanner or a similar tool.

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- Remove the Bump Integrator Spindle by pulling it carefully outwards off the shaft. Be very careful of the BI spring that is coiled just on the inside of the Bump Integrator (see below).

Removing the BI Spring

The BI Spring is held in place at each end by its retaining hooks which hook onto two spring retaining screws on the BI. One retaining screw is on the on the BI Unit and the other on the inside of the BI spindle. Unhook the BI spring from these retaining screws.

NOTE: You do not need to remove the retaining screws to remove the BI Spring, the ends of the spring will unhook off the screws.

Installing the BI Spring

A new spring supplied by Data Collection Ltd comes in a metal retaining ring which holds together as shown below.

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- Carefully remove the retaining ring that holds the BI spring together
- Attach the outer Spring retaining hook to the spring retaining screw attached on the inside of the BI Spindle.
- Attach the inner spring retaining hook to the spring retaining screw attached on the BI Unit.
- Carefully loop the Spring tight inside the BI Spindle.
- Line up the key on the BI Unit shaft with the hole on the inside of the BI spindle and push the BI Spindle onto the shaft so that the key and hole latch.
- Replace spindle nut and tighten.

Install BI Wire

- Insert BI wire through the hole on the spindle to put it back in place
- Insert wire clamp removed earlier then thread through the BI wire approx. 10mm from end of BI wire then make a loop of 20mm diameter at the end of the BI wire, then tighten the 2 wire clamp retaining screws to hold the loop of wire together.

Install in Vehicle

- Check that the spindle can turn approximately four turns, and then re-install back into vehicle.
- The Bump Integrator should be re-calibrated after the installation of a new spring.

BI Calibration – Overview

Calibration Requirements

Each vehicle responds differently to roughness due to variations in the springs, dampers and tyres. It is therefore essential to calibrate each roughness survey vehicle against a standard roughness so that its measurements can be related back to the standard roughness.

Frequency:

- Before each major roughness survey or every 5000 km

International Roughness Index

This appendix describes the method which should be followed to calibrate roughness meters to the International Roughness Index (IRI). It is based on the work presented in Sayers et al. (1986) and Sayers

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(1995)[19].

The ROMDAS CD contains the background reference reports listed below which should be reviewed in addition to the material presented here.

Report Name	Contents
❑ Guidelines on Calibrating Roughness Meters	World Bank publication which is the standard reference for IRI calibrations
❑ Little Book of Road Profiling	University of Michigan report giving excellent overview of calibrtions
❑ Everything you want to know about roughness	Summary of roughness calibrations
❑ Austroads Validation of Roughness Measurements	Technical report on calibration and validation issues
❑ Subjective Estimates of Unpaved Road Roughness	World Bank publication on visually estimating road roughness
❑ Using MERLIN for Calibrating Road Roughness	Extract from TRL publication on MERLIN
❑ LTPP Dipstick Operators Manual	LTPP guide on manual profiling with the Dipstick. Similar to Z-250
❑ LTPP Manual for Profiler Measurements	LTPP guide on profile measurements

International Roughness Index

Definition

Sayers (1995) gives the following definition for the IRI:

1. IRI is computed from a single longitudinal profile. The sample interval should be no larger than 300 mm for accurate calculations. The required resolution depends on the roughness level, with finer resolution being needed for smooth roads. A resolution of 0.5 mm is suitable for all conditions.
2. The profile is assumed to have a constant slope between sampled elevation points.
3. The profile is smoothed with a moving average whose baselength is 250 mm.
4. The smoothed profile is filtered using a quarter-car simulation, with specific parameter values (Golden Car), at a simulated speed of 80 km/h.
5. The simulated suspension motion is linearly accumulated and divided by the length of the profile to yield IRI. Thus, IRI has units of slope (usually m/km).

[19] Sayers, M.W., Gillespie, T.D. and Paterson, W.D.O. (1986). *Guidelines for the Conduct and Calibration of Road Roughness Measurements.* World Bank Technical Paper No. 46, The World Bank, Washington, D.C. Available on ROMDAS CD.
Sayers, M.W. (1995). *On the Calculation of IRI from Longitudinal Road Profile.* TRB Paper No. 950842, Transportation Research Board, Washington, D.C.

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Underlying Model

The underlying IRI model is a series of differential equations which relate the motions of a simulated quarter-car to the road profile. Figure B.1 illustrates the quarter-car model used and the parameters adopted (Sayers, 1995).

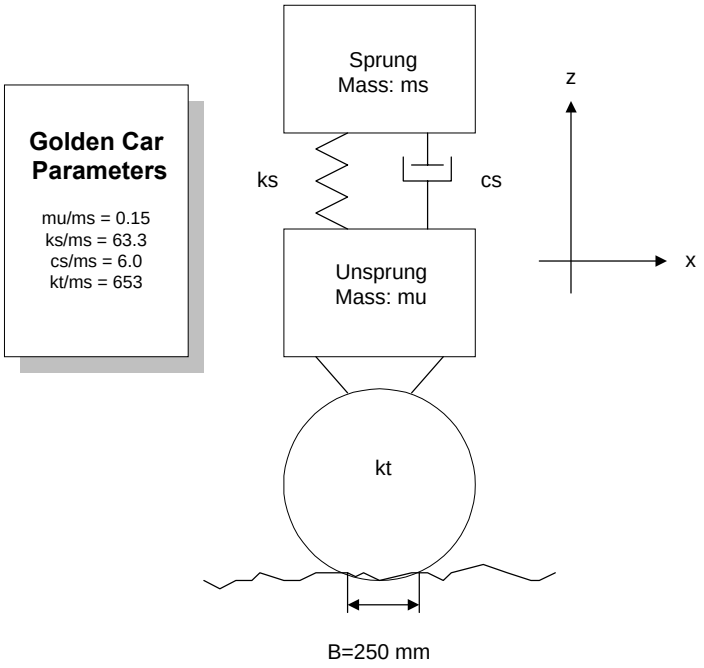

Figure B.1: IRI Quarter-car Model

The IRI is the accumulation of the motion between the sprung and unsprung masses in the quarter-car model, normalised by the length of the profile. Mathematically this is expressed as:

$$IRI = \frac{1}{L} \int_0^{L/V} \left| \dot{z}_s - \dot{z}_u \right| dt$$

where IRI is the roughness in IRI m/km
L is the length of the profile in km
V is the simulated speed (80 km/h)
$\dot{z}_s$ is the time derivative of the height of the sprung mass
$\dot{z}_u$ is the time derivative of the height of the unsprung mass

Algorithm

The algorithm used to calculate the IRI is described in Sayers, et. al. (1986) and elaborated on in Sayers (1995). Both references provide a computer listing for calculating the IRI; Sayers, et al. (1986) in BASIC

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and Sayers (1995) in FORTRAN.

The RoadRuf software, provided by the University of Michigan, is the standard analysis software for IRI calculations. It is available on the ROMDAS CD under menu:

Software Extras|Roughness Analysis|UMTRI Road Roughness Software

Calibration Steps

In order to calculate the IRI the following steps must be taken:

- identify calibration test sections;
- determine the elevation profile **of each wheelpath** for each test section;
- using the profile data, run a quarter-car simulation for the reference vehicle over each wheelpath and calculate the wheelpath IRI;
- establish the average IRI for both wheelpaths.

Selecting and Profiling Calibration Sections

Calibration Section Characteristics

The objective of calibration section profiling is to obtain an accurate representation of the road profile. It is necessary to identify calibration sections which cover the full range of roughnesses the survey is likely to encounter[20]. These sections should have the following characteristics:

- the sections should be 200-300 m long (400-450 with MERLIN) with adequate geometry before and after the section to ensure that they can be travelled at a constant speed;
- the roughness should be fairly uniform along its length insofar as there are not short sub-sections with high roughnesses interspersed with sub-sections containing lower roughnesses;
- the surface should not be broken (i.e. potholes or bad depressions) so that the profiling survey can get the true profile;
- they should have low traffic volumes so that the roughness will not change significantly over time and so that you will survive the calibration survey;
- one should not have combinations of rigid and flexible, or machine laid and hand laid, sections since these can have different roughness properties, although this is not always possible in some countries if one wants to cover the full range of roughnesses;
- the beginning and end of sections should be clearly marked;
- permanently mark the wheelpaths for profiling using nails and painting them white. During recalibration you can then readily remark the wheelpaths.

[20] This can be done using an uncalibrated roughness meter to differentiate between sections with different roughness levels.

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Number of Sections

The number of test sections required is calculated by dividing 4500 by the site length in m, with a minimum of 8 (Sayers, et al., 1986). For example, with 300 m test sections 15 sites would be required.

Profiling Techniques

The sections should be profiled at maximum intervals of 300 mm using one of the techniques below:

- ROMDAS Z-250 Reference Profiler
- TRL MERLIN;
- TRL Beam;
- A rod-and-level survey[21];
- DIPSTICK;
- Profilometer.

Irrespective of what method is used, the device should be calibrated before the survey. Each instrument will have its own procedures for calibration and these should be carefully followed.

Z-250 Profiling

Step 1 – Clear the Site

It is useful to walk the site and clear off any loose stones and debris which may cause the feet of the Z-250 to slip. It is particularly important to ensure that there is no water on the section as this could affect the Z-250 electronics.

Step 2 – Mark the Site

The beginning and end of the site should be marked with nails or another form of permanent marker. This will enable resurveys to be done on the section. When calibrating the vehicle it is useful to put a post in adjacent to the start of the section so that it can be readily identified from the moving vehicle. Alternatively, a paint strip across the pavement will suffice.

It is necessary to mark the wheelpaths to ensure that the Z-250 measurements follow the wheelpath. If the wheelpaths are clearly identifiable this is straight forward. When they are not clear it is necessary to adopt a consistent rule for locating the wheelpaths. For example, the LTPP study identifies the centre of the lane and then takes the wheelpaths as 0.826 m either side of this centreline.

[21] For a description on using a rod-and-level survey for profiling test sections see:
Visser, A.T. (1982). *A correlation study of roughness measurements with an index obtained from a road profile measured with rod and level.* Technical Report RS/2/82. National Institute for Transport and Road Research, CSIR, Pretoria.

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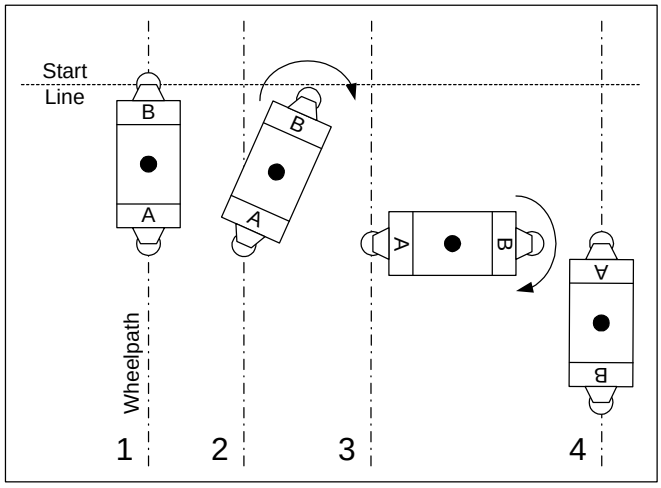
Use a chalk line to put a line down each of the wheelpaths. Alternatively, run a string along the wheelpath and put paint marks in at regular intervals.

Step 3 – Record Data

- Place the Z-250 at the start of the section
- Start the Z-250 software
- If the automatically selected file name is not appropriate change the name by clicking on the top left icon and entering a new name.
- Hold the Z-250 handle vertical and select the **Start Data Logging** button. The Z-250 will take a reading and beep when it is done.

The Z-250 is 'walked' along the road. As shown in the figure below, this consists of rotating the Z-250 clockwise around its lead foot. This results in a set of elevation measurements between every placement.



Movement of Z-250

During the survey the Z-250 displays the chainage along the section (in m) as well as the elevation (in mm). An example of this display at 2.00 m (8th placement) is shown below (left).

It is sometimes necessary to pause the survey, for example to allow for a change of operator or because of traffic conditions. In this case the **Pause** button should be pressed which will stop the data logging until the **Resume** button is pressed (below, left).

Errors happen and these are handled by selecting the **Error** button. As shown below (right) this allows the operator to repeat up to the last three measurements. The data are flagged in the file and can be manually removed.

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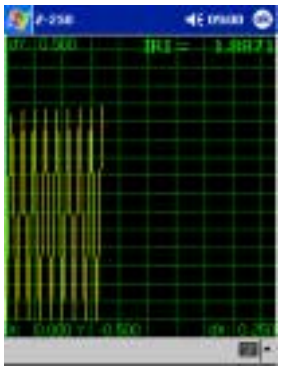
Step 4 – End Survey

At the end of the survey press the **End** button. The roughness in IRI m/km will be displayed (below, left) and, optionally, a plot (below, right).



Step 5 – Download Data for Analysis

Two files are saved for each survey:

- **Text File:** A text file which contains 3 columns the distance, the logged elevation data and the summed or longitudinal profile data.
- **RoadRuf .erd File:** An erd file, which has the necessary header information to allow the file to be imported into the Road Ruf program for further analysis.

These files can be copied to a PC for further analysis. This is done as follows:

- Connect the data logger to the PC
- Ensure that the ActiveSynch connection is open
- Start **Windows Explorer**
- Open the **Mobile Device**
- Locate the **Z-250 Data Directory**
- Select the appropriate files
- Right click and select **Copy**
- Paste the files to the appropriate folder on the PC

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As described in[22], the MERLIN (a **M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation) was devised to measure the roughness of a calibration inexpensively, quickly, easily and reliably.

The ROMDAS CD contains extracts from the TRL report describing the MERLIN. DCL can supply plans for its manufacture.

MERLIN consists of a rigid metal frame, 1.8 m long, with a wheel at the front, a curved foot at the rear and a moveable probe midway between the two which rests on the road surface. If the road were always smooth, the probe would always lie on a straight line between the bottom of the wheel and the rear foot. If the road were uneven, the probe would usually be displaced above or below the line.

To measure the displacements, the probe is attached to a pivoted arm, at the other end of which is a pointer which moves over a chart. The arm is pivoted close to the probe so that a movement of the probe of 1 mm will produce a pointer movement of 1 cm.

The roughness of a section of road is measured by wheeling the MERLIN along the road with the handles raised. Once every wheel revolution, the handles are lowered so that the probe and rear foot touch the ground and the resulting pointer position is recorded as a cross on a chart. Two hundred measurements are made to produce a histogram. The width of the central 90 per cent of the histogram is measured form the chart and this can be converted directly into roughness.

Although the MERLIN is manufactured to rigid specifications, its accuracy is predicated on the exact ratio of 10:1 or 5:1 being maintained. However, with use it is possible for this to be lost. Accordingly, it is necessary to apply a correction factor to the readings. This correction factor is established as follows (Kampsax, 1992)[23]:

- Place the MERLIN on a smooth level surface, such as a terrazzo office floor;
- Tape a blank sheet of A4 paper onto the chart holder;
- Adjust the probe until the pointer is roughly in the centre of the paper;
- Mark the position of the pointer on the paper;
- Slide under the probe a steel plate of known thickness (such as the 6 mm plate supplied by FARNELL) - the exact thickness is not important but it must be measured accurately with a micrometer or vernier gauge;
- make a second mark on the paper and measure the distance between the two marks with a ruler;
- repeat several times at different locations on the floor and calculate the average movement of the pointer.

22 *TRL Overseas Newsletter*, February 1993 - No. 10. Transport Research Laboratory, Crowthorne.
Cundill, M.A. (1991). *The MERLIN Low-Cost Road Roughness Measuring Machine.* TRRL Report 301, Transport Research Laboratory, Crowthorne.

23 Kampsax (1992). *ADB Farm-to-Market Roads Project Phase II, Road Maintenance Management Systems, Volume I - System Concepts and the Database, Appendix H: Roughness Meter Calibration.* Report to the Asian Development Bank

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MERLIN Survey in Gujarat, India. The wood was the width of the vehicle track and the pavement was painted to precisely locate the wheelpaths

The correction factor for the machine is given by:

$$CF = (10 \times T)/PM$$

where CF is the MERLIN correction factor
T is the thickness of the plate in mm
PM is the average movement of the pointer in mm

If you are using the 5:1 setting the 10 in the above equation would be replaced by 5.

For example, if the plate thickness is 6 mm and the average pointer movement is 62 mm the correction factor is 0.97.

The roughness is calculated using the following equation (Cundill, 1991):

$$IRI = 0.593 + 0.0471\ D\ CF$$

where D is the roughness in terms of the Merlin scale in mm

The above equation is based on machine laid surfaces. Research in Indonesia has suggested the following equation for hand laid Penetration Macadam surfaces (Cundill, 1995)[24]:

$$IRI = 1.913 + 0.0490\ D$$

The equation was developed from 8 data points over the range of $97 < D < 202$ ($6.7 < IRI < 11.3$) so it must be used with some caution.

In addition to calibrating the probe, it is also necessary to check on the circularity of the front wheel (Kampsax, 1992). As it is difficult to stop in exactly the same position each time, a part of the wheel circumference

[24] Correspondence with author.

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should be found which is of constant radius. This can be done by keeping the MERLIN so that the rear foot and probe remain in the same location. Then make marks on the paper while turning the wheel in increments of 5 - 10 cm of its circumference. When a section is found that gives constant readings, mark it on the rim with white paint.

Calculating IRI From Profiles

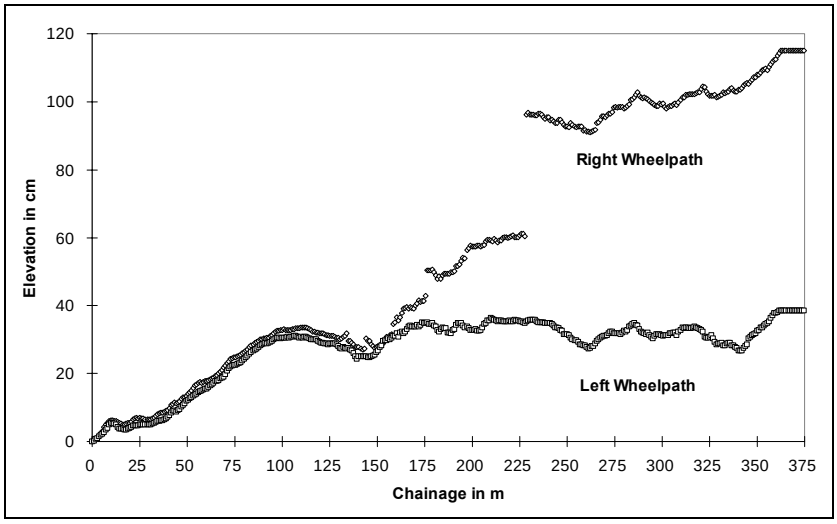
Overview

When using the ROMDAS Z-250, a rod-and-level survey, DIPSTICK, or any other profiler output, it is necessary to calculate the IRI from the elevation profile. This section describes the use of the RoadRuf software for calculating IRI.

Check the Data

The first stage is to reduce the data into the appropriate format. The Z-250 stores data in the ERD format for use with Road Ruf.

It is recommended that the individual profile data be reviewed graphically so as to ensure that there are no errors in recording or processing. The importance of this is illustrated in the figure below which is from a calibration using the DIPSTICK in Myanmar. During the data entry there were several transcription errors which led to discontinuities in the right wheelpath elevation profile. Had these not been corrected the IRI would have been 26.0 instead of 14.7.



Example of DIPSTICK Data Problem from Myanmar

Locating the Program

RoadRuf is provided on the ROMDAS CD under the menu item:

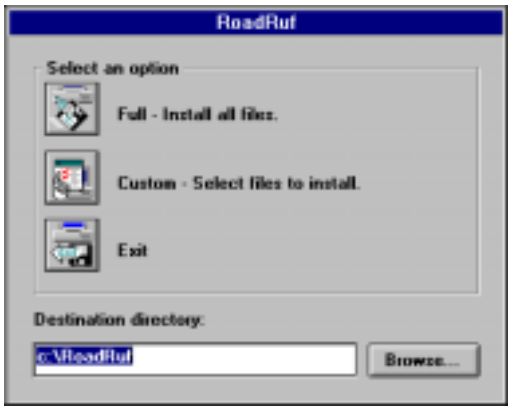
Software Extras|Roughness Analysis|UMTRI Road Roughness Software

It can also be downloaded from the Internet through the University of Michigan Transport Research Institute web page at:

http://www.umtri.umich.edu/erd/roughness/index.html

Installing the Software

Selecting the menu item opens the RoadRuf install program (see below). Select the appropriate destination directory and select **Full – Install All Files**.



The software will be installed to the directory. When prompted to create 'Program Manager Groups' select **Yes**. A series of screens will be temporarily opened and the software install will finish.

Starting the Analysis

When the RoadRuf software is started the screen below is displayed.

- Select the **Start** button

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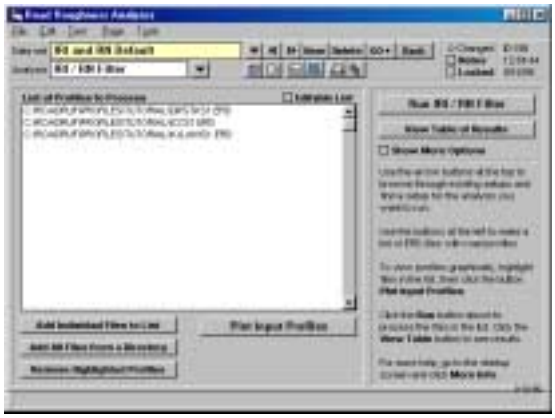
Default Settings

The RoadRuf control screen is shown below. It is necessary to confirm the settings for the analysis.



Select the **Show More Options** box and the **Create Output Plot Files** box to see all setup options. The screen will be as shown below.

On the analysis screen the settings should be:

- Data Set - IRI and RN Filter
- Analysis - IRI/RN Filter

Select **Profile and Units Setting** and the menu to the right will be displayed. Ensure that the **Default (SI Units)** is selected.

Ensure that under **Analysis Settings** the selection is for **Default from UMTRI**.

Files

It is necessary to select the files for analysis. RoadRuf uses .erd files

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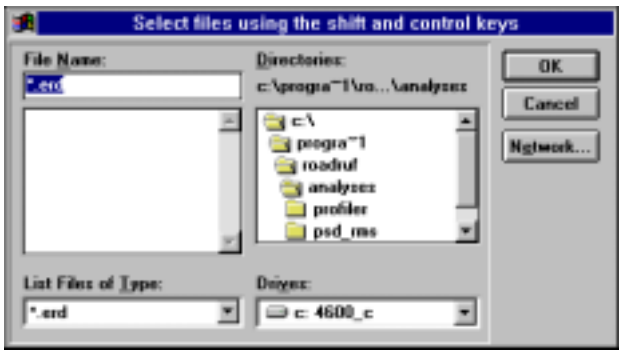
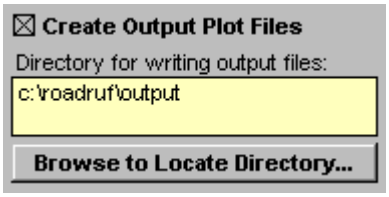
which are created by the Z-250 in the survey. These have a specific format as well as a header.

Files are selected using the **Add Individual Files to List** button which opens the window below. It is necessary to have copied the Z-250 files to the PC before they can be analysed. The folder containing the Z-250 files should be selected.



Ensure that the **Create Output File** is selected. The results will be written to the folder listed in the window below. An alternative location can be selected.



Running An Analysis

Click on Default UMTRI and view the print interval, this is where the analysis length is selected, usually 100, change to the desired value.

To run an analysis select **RUN IRI/RN Filter**. Each of the files in the list will be analysed (*ie* it is possible to analyse multiple files in a single run). When the analysis is completed, select **View Table of Results**. This is a display of the IRI for the section and also for the individual 100m intervals within the section. Note the RN or Ride Number is also displayed.

Sample Analysis

When the RoadRuf software was installed sample data files from the LTPP study were installed to c:\RoadRuf. To illustrate the analysis these will be processed and reviewed.

- Highlight all the files in the 'List of Files to Process' window
- Select **Remove Highlighted Profiles**
- Select **Add Individual Files to the List**
- Locate the folder **c:\RoadRuf**
- Highlight and select all the .erd files in the folder
- Select **OK**. The RoadRuf analysis window will look like that below

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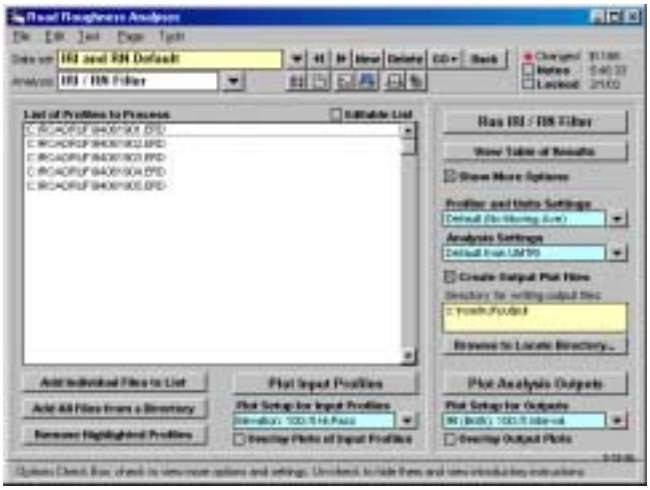
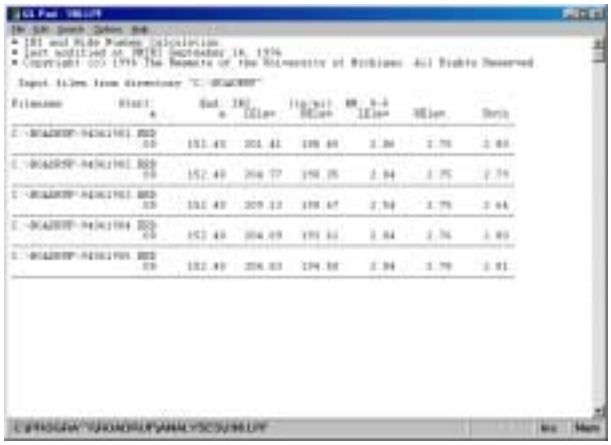


- Select **Run IRI/RN Filter** to analyse the profiles
- Select **View Table of Results** to see the results of the analysis. The data below will be shown. This shows that the sections were 152.40 m long and displays the IRI (in inches/mile) along with the Ride Number



- Highlight the C:\ROADRUF\94061901.ERD profile name in the file list
- Select **Plot Input Profiles**. The elevation profile will be plotted as shown below.

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NOTE: It is important to carefully review these profiles as it is possible to have discontinuities due to measurement errors. These will lead to wrong values of the IRI. When these are found the data should be edited to correct the values.

- Select **Plot Analysis Outputs** to display the IRI accumulation along the section (see below). Any sudden changes may be signs of data errors.

Additional analyses, for example power spectral densities, are available. Reference should be made to the RoadRuf User's Guide and Tutorial which are installed with the software.

Calibration Survey

Preparing the Vehicle

The calibration survey is conducted by operating the vehicle over each calibration section and recording the roughness meter output. There are a few practical considerations in calibrations and roughness surveys:

- calibrate the odometer;
- drive vehicle for minimum of 10 km to ensure that tyres are at operating temperature;
- ensure that the tyre pressure is at the correct operating pressure[25];
- load the vehicle to the same level that it will be at during the survey (e.g. driver, operator, fuel);
- before starting a major survey install new tyres and dampers a few weeks before the survey so they have time to be run in

Survey Form

Appendix H contains a form to be used for recording data during calibration surveys. It is recommended that this form, or a variation, be used to ensure that all the necessary steps are followed.

[25] The tyre pressure can be set either warm or cold as long as the same state is used in all calibrations and operations.

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Collecting the Data

The response of a vehicle to roughness is a function of speed. Thus, different roughness values will arise at different speeds for the same calibration section. Since it is practically impossible to conduct a roughness survey at a constant speed, it is recommended that calibration be done at a range of speeds. This is done by repeating the calibration survey with the vehicle operating at different speeds.

Each measurement run should be started well in advance of the start of the test section in order to bring the vehicle up to a steady state speed before reaching the mark. At the start of the test section the ROMDAS recording is started and it is halted at the end of the section.

Establishing the Number of Runs

A sufficient number of calibration runs should be made to ensure statistical significance of the mean. Since we are dealing with small samples ($n \leq 30$), the t Distribution should be used to establish the number of runs to give a desired level of confidence. If the roughness has a Normal Distribution, then small-sample confidence intervals for the mean roughness are obtained by:

$$IRI \pm t\frac{s}{\sqrt{n}}$$

where
- IRI is the mean roughness in IRI m/km
- s is the standard deviation of roughness in IRI m/km
- n is the number of runs
- t is the critical value for the t Distribution

Hamilton (1990)[26] gives the values below for 90 and 95 per cent confidence intervals using the t Distribution.

Sample Size	Critical t Value by Confidence Interval	
	90	95
3	2.920	4.303
4	2.353	3.182
5	2.132	2.776
6	2.015	2.571
7	1.943	2.447
8	1.895	2.365
9	1.860	2.306
10	1.833	2.262

[26] Hamilton, L.C. (1990). *Modern Data Analysis - A First Course in Applied Statistics.* Brooks/Cole Publishing Company, Pacific Grove, California.

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On the basis of the above equation, we can define a new statistic as:

$$\beta = t\frac{s}{\sqrt{n}}$$

The results are acceptable when β is within a certain percentage of the mean. For most applications we would set a limit of a 10 per cent confidence interval. Thus, the results are acceptable if:

$$\beta \leq 0.10\ BImean$$

Performing the Calculations

The following is how we would use this theory:

1. Conduct a minimum of 5 runs of the roughness meter and record the roughness of each run.
2. Calculate the mean roughness (BI) and the standard deviation (s).
3. Calculate the statistic β. For example, if there were 5 runs with a mean of 21 and a standard deviation of 0.80 you would calculate it as (95%):

$$\beta = 2.776\frac{0.80}{\sqrt{5}} = 0.99$$

   In the above equation the value of 2.776 is from Table above and corresponds to 5 runs with 95% confidence.
4. Check that β is within 10 per cent of the mean. In the above example β = 0.99 which is less than 2.1 (0.10 * 21) so it would not be necessary to do any additional runs.

An Excel template is available on the ROMDAS CD to perform these calculations. If you do not have access to Excel there is a freeware spreadsheet program supplied on the ROMDAS CD[27]. The template is located under menu:

ROMDAS Software|Excel Templates|Roughness Meter Calibration Excel Template

When opened, the display will be as shown below. The data are entered for up to 8 runs and the spreadsheet calculates the mean, standard error, β, and then indicates whether the mean is statistically significant at 90% and 95% confidence with the terms 'Pass' or 'Fail'.

[27] The spreadsheet is located under: **Software Extras|Utilities|Applications|Spreadsheet Software**

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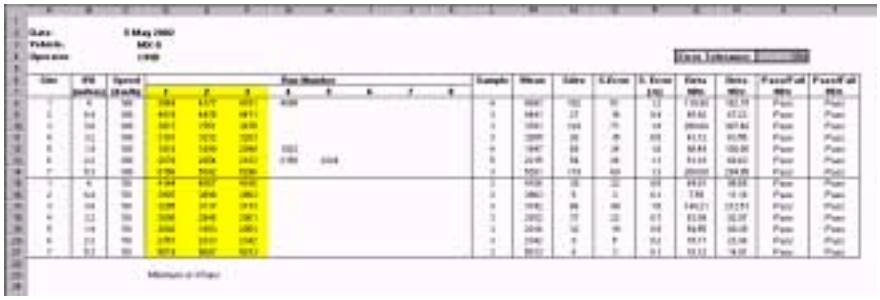

If any of the sites 'Fail', check the data for outliers or perform repeat runs.

Calibration Equations

Analysis of Data

The data need to be analysed to develop a calibration equation. This equation converts the raw ROMDAS roughness measurements to calibrated IRI m/km. The analysis should be done using the roughness calibration template located at:

Software|Templates|Roughness Calibration.xlt

Calibration Equations

ROMDAS converts the raw roughness meter counts to the calibrated roughness (*ie* the IRI) using a general equation of the following form:

$$CALIB\_RGH = A0 + A1 * RAW^{A2} + A3 * RAW^{A4} + A5 * \exp(A6\ RAW)$$

where	CALIB_RGH	is the calibrated roughness in IRI m/km
	RAW	is the raw roughness meter counts in counts/km
	A0 to A6	are regression coefficients

The above formulation has been designed for the maximum flexibility. Not all coefficients will be used in a model as it is typical to have simple linear or polynomial functions.

There is no limit to the number of equations that can be used with ROMDAS. Each equation will be used for all speeds below the mean of the previous and following speeds. For example, if equations were supplied for 50 and 100 km/h the first equation would be used for speeds below 75 km/h and the second for speeds above 75 km/h.

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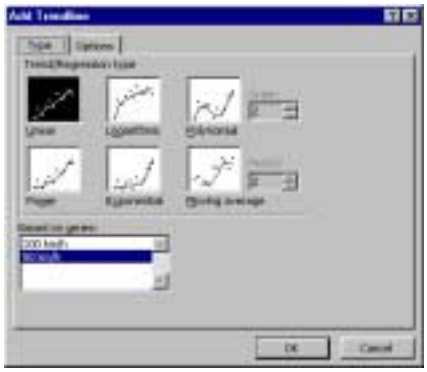
Determining Coefficients

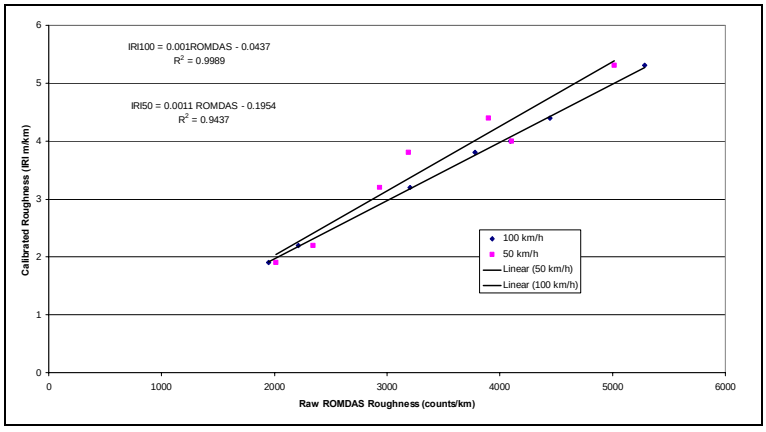
The relationship between raw roughness and IRI is usually linear so the following approach can be used in Excel to establish the regression coefficients:

- Highlight the series of interest and right clicking the mouse.
- Select **Add Trendline** from the menu.
- Select the type of regression (see below)



- Select **Options**
- Select **Display Equation on Chart** and **Display R-squared on Chart**.
- Click **OK** and the regression will be fitted

As shown in the example below, a linear equation will be fitted to the data.



If the data are non-linear, you can try and fit curves using the same procedure, except selecting different types of curves. For complicated curves it is necessary to use a non-linear regression program and one is provided on the ROMDAS CD[28].

28 The program supplied is called NLREG and it is distributed with the permission of its author. NLREG is an extremely powerful yet easy to use regression package which runs under MS-DOS. It is distributed as Shareware so should you choose to continue using the program you are expected to register it with the author. Details of the current registration fee is supplied in the file REGISTER.DOC which is found in the subdirectory with the program. The terms of usage are given in the file READ.ME which is in the same subdirectory.

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You must be careful to ensure that all the coefficients are statistically significant in the calibration equation (i.e. the Prob(t) < 0.05) and that there is an acceptable standard error. Please refer to any standard statistical text book or the NLREG manual for a discussion of statistical significance.

Low Speed Effects

The roughness is a function of speed which is why the roughness calibration coefficients should be specified for different speed ranges. However, a situation may arise where the vehicle is forced to travel at a very slow speed due to the high level of roughness. Under these situations the instrument will not give correct readings under typical calibrations.

Montgomery Watson (2001)[29] found in Tonga that *"… the vehicle could not travel* [at] *the desired survey speed was because the road physically became too rough. The rougher the road the slower the speed of the survey vehicle."* This effect is illustrated in the figures below.

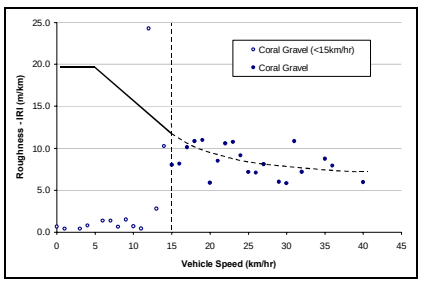
In total, 28% of the unsealed network and 3% of the sealed network had to be driven at speeds below 15km/hr. The following equations were developed to assign an estimated roughness value to these road sections (Montgomery Watson, 2001).

Unsealed

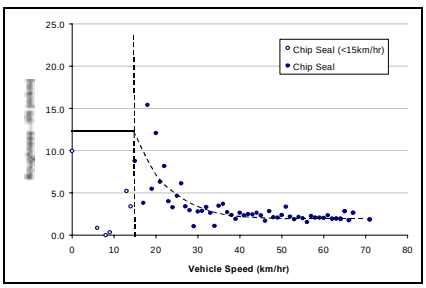
IRI = 20	for < 5km/hr
IRI = 24 – 0.8*Speed	for 5km/hr to 15km/hr

Sealed

IRI = 12.5	for < 15km/hr



Speed Effect – Unsealed Roads



Speed Effect – Sealed Roads

29 Montgomery Watson (2001). *Tonga Transport Infrastructure Project: HDM-4 Establishment Technical Reference*. Report to the Ministry of Works, Christchurch.

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Appendix C: Installing and Calibrating the Laser Profiler

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Overview

Laser Profilometer System

The ROMDAS Laser Profilometer system consists of sensors bolted to an adjustable mounting system which attaches to any vehicle on the trailer hitch on the rear of the vehicle. A profiler contains the laser and accelerometer units and there associated processors.

The Laser unit senses the distance from a reference level on the instrument to a target using reflected laser beam geometry. The laser beam is reflected from the target through an optical lens system onto a linear sensitive strip. The position of the reflected laser spot along this strip is measured and processed by the system. The non-linear nature of the response of this strip and any optical aberrations are corrected using a detailed calibration table held within the laser processor. Laser elevation readings are calculated at a rate of 16kHz. An 8 sample moving average low pass filter is then applied to the acquired data before the laser elevation data is reported.

The vertical acceleration of the profiler is measured by a high precision accelerometer mounted in the same vertical plane as the laser itself. There is a dedicated processor for measuring acceleration signals. The acquisition of acceleration data occurs at a rate of 16kHz. The constant one gravity signal experienced by the accelerometer is removed by circuitry within the system. The processing elements within the acceleration signal chain are effectively AC coupled, and have a time constant of approximately 10 seconds. This ensures the dynamic range of the system is not exceeded during normal use, and the bandwidth of interest is not compromised.

The Laser and accelerometers are both contained in an IP65 rated housing

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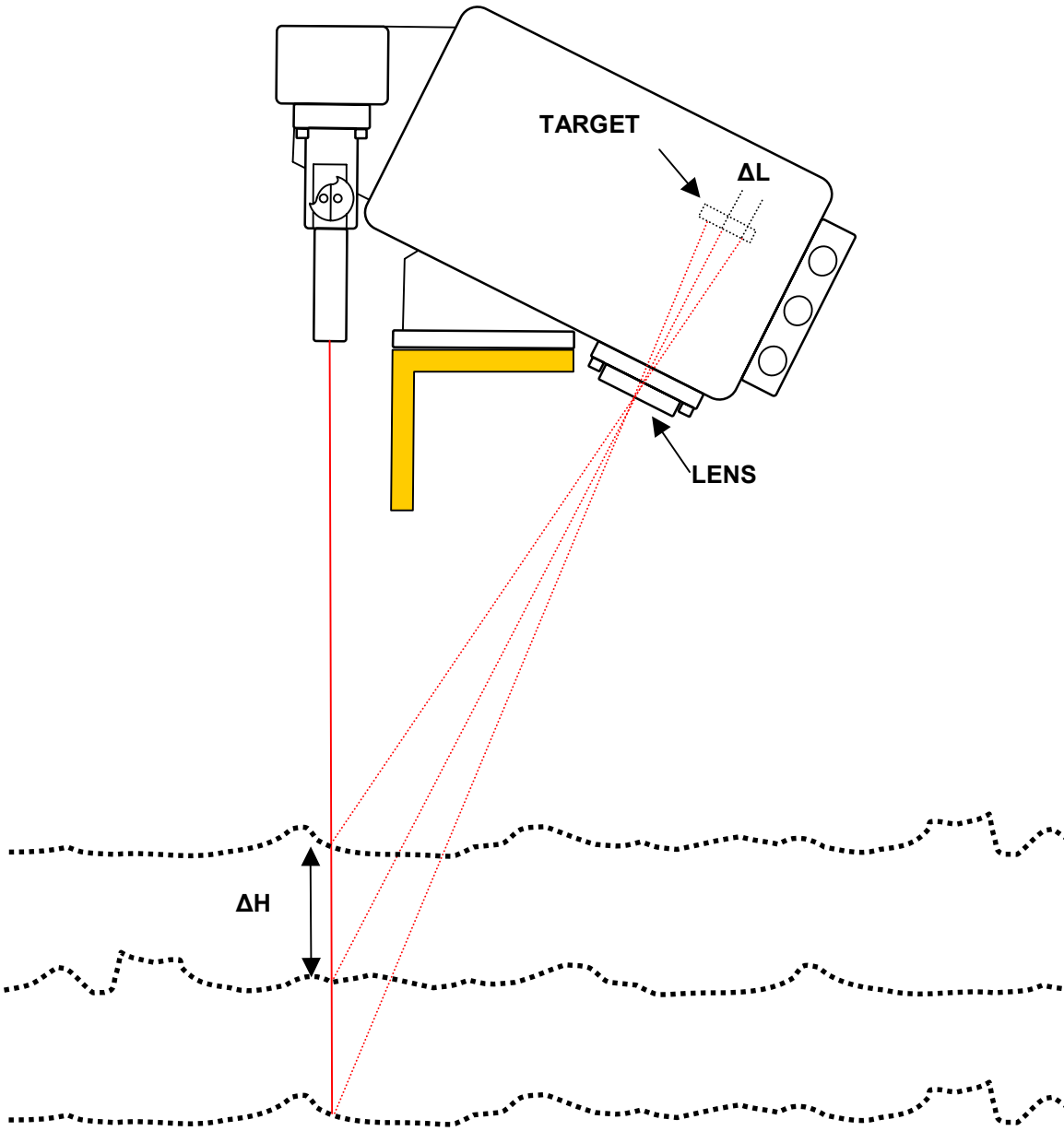

- Invisible laser fires vertically at surface at sampling speed.
- Internal optical target senses reflected spot
- Height of spot related to its horizontal position on the target.
- Dynamic height-range = ± 128mm

This Appendix

This appendix describes the installation and calibration of the Laser, as well as additional background information which may be of interest to users.

Laser Safety

Overview

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Lasers emit an invisible light. Avoid exposure to the beam

The beam is hazardous to the eye if viewed directly or via spot reflection at close range.

The operational status of the lasers can be seen within the software – so there is no need to look at the lasers directly.

When adjusting and calibrating the lasers, ensure the use of the correct wavelength laser safety glasses.

lasers used in outdoor and similar environments should only be operated by personnel adequately trained in their use

The Laser has the following mechanical and electrical safety features.

- The laser is powered through the Laser DMI Interface, which can only be turned on with the key.
- Mechanical Shutter to isolate the Laser beam
- Configurable low speed cut-off to laser activation input

Laser DMI Interface Keylock

The laser is powered through the Laser DMI Interface which is powered by the keyed switch. The key should be removed when the Laser is not in use to ensure that it is not operated by untrained personal.

Laser Mechanical Shutter

The laser is equipped with a mechanical shutter to isolate the laser beam. Ensure the shutter in the closed position when the laser is left unattended

Laser Minimum Speed Electrical Interlock

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Each laser is also equipped with a 12V activation input for safety interlock purposes. Although the laser electronics can be powered on with the key on the Laser DMI Interface the laser diode itself will not activate unless an activation signal is provided. The activation signal interlock is powered by the Laser DMI interface when the minimum speed cut-off is exceeded.

When the Laser DMI is in Test mode it simulates a speed of 80km/h. The Min Speed will be exceeded and the Laser will activate. Observe Laser safety when in Test mode (the DMI Test mode is activated by the ROMDAS software when doing stationary tests such as the Elevation and Bounce tests – particular care must be taken when using these options).

Installing the Laser Profilometer

Mounting on Vehicle

The Laser Profiler is mounted to the vehicle using the supplied kit of mounting parts. The parts are shown at the end of the instructions. The only tool required for assembly is a ¼' ball-end hex wrench which is also supplied with the kit.

The mounting hardware has been designed for easy adaptation to any test vehicle, and to facilitate accurate adjustment of height and positioning of the Laser Profiler for best performance.

The assembly of the Laser Profiler requires several steps to complete. When finished, the mounting assembly should look like Photo 1.

Photo 1

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The Laser Profiler Mounting Hardware is attached to the test vehicle using the Vehicle Mounting Bracket Photo 2. This bracket has 8 holes (left side of photo) to attach the Laser Profiler mounting bar.

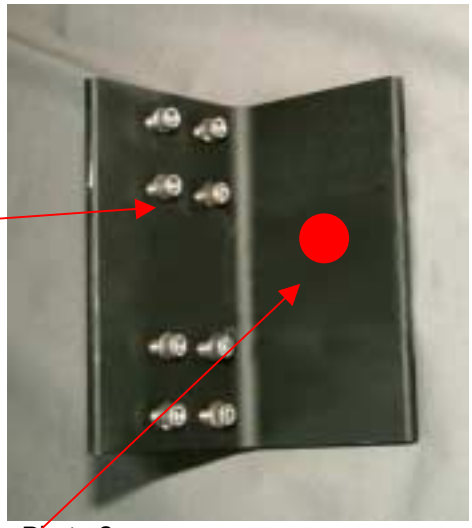

Photo 2

Laser Profiler Hardware Mounting Holes

The first step in the assembly is to attach the mounting bracket to the vehicle. The most convenient way of doing this is to attach the bracket to a standard trailer hitch. This can be done by using the hole normally used for the trailer towing ball. In this case, you must drill a matching hole in the Mounting Bracket and then bolt the bracket to the trailer hitch

Drill Vehicle Mounting Holes Here

For improved stability, you can drill a second mounting hole in both the bracket and the hitch. This hole will prevent the bracket from rotating.

If you have a receiver style trailer hitch as shown in **Photo 3**, then you should modify the mounting bracket by welding a matching bar to the mounting bracket as shown below.

Photo 3

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Using the 5/16 inch x 7/8 inch cap screws (Photo 19) and lock washers (Photo 29), attach 4 double T-Nuts (Photo 20) to the Vehicle Mounting bracketn in **Photos 2** and **4**. In a later step, you will attach the mounting bar extrusion to the bracket by sliding the bar over the T-Nuts and tightening the cap screws.

Photo 4

When attached to the trailer hitch, the Vehicle Mounting Bracket should look like **Photo 5**

Photo 5

Assemble the laser Profiler Mounting Brackets. When finished, you should have 2 brackets that look like **Photo 6**.

Photo 6

First, attach the 300mm extrusion (Photo 13) and two 10 hole joining plates (Photo 16) as shown in Photo 7. Attach the plates to the 300mm extrusion using two double T-Nut (Photo 20) and four 5/16 inch socket head screws (Photo 19) for each plate. Attach the Laser Mounting Bracket (Photo 18) to the joining plate using two triple T-Nuts (Photo 30) and six cap screws (Photo 19) for each plate.

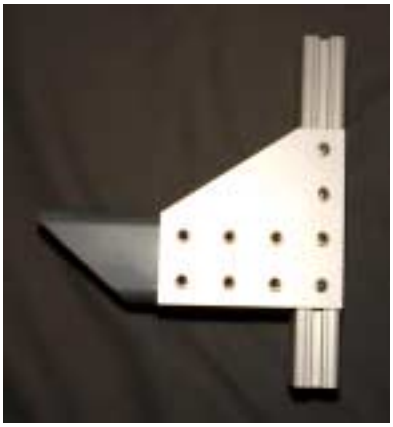

Photo 7

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Prepare one 16 hole mounting plate Photo 15) for each laser by attaching four double T-Nuts (Photo 20) and 4 single T-Nuts (Photo 21) as shown in Photo 9

Photo 8

Now, attach one of the 16 hole plates to each of the laser mounting subassemblies as shown in Photo 6. The Laser Profiler Mounting Bracket(s) are now complete.

Next, prepare the main mounting bar for attachment to the Vehicle Mounting Plate. The main mounting bar consists of three 700 mm aluminium extrusions (Photo 14) that are joined together using 4 butt fasteners (Photo 31) at each joint (two on the top, and two on the bottom). As show in Photo 9

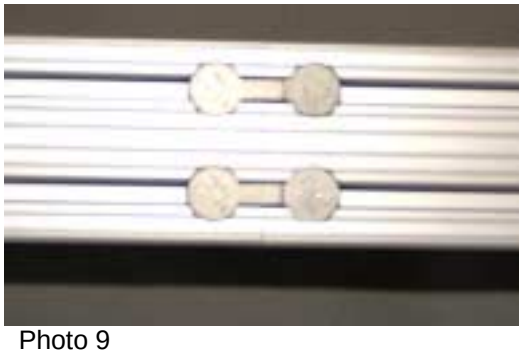

Photo 9

When assembled, the main mounting bar should look like Photo 10. The main mounting bar can now be attached to the vehicle by sliding it over the T-Nuts on the vehicle mounting plate.

Photo 10

Attach the laser to the Laser Mounting Bracket using the two Laser Mounting Bolts and Lock Washers (Photo 28), and slide the final assembly onto the main mounting bar.

Attach the end caps to all extrusions using the supplied cap screws, and tighten all connections

Photo 11

You can use the sliding features of the extrusion system to adjust laser spacing to match the wheel paths, and to raise or lower the laser to the required height of 430 mm from the ground to the top of the laser mounting attachment. The Laser has a dynamic height range of ± 128mm.

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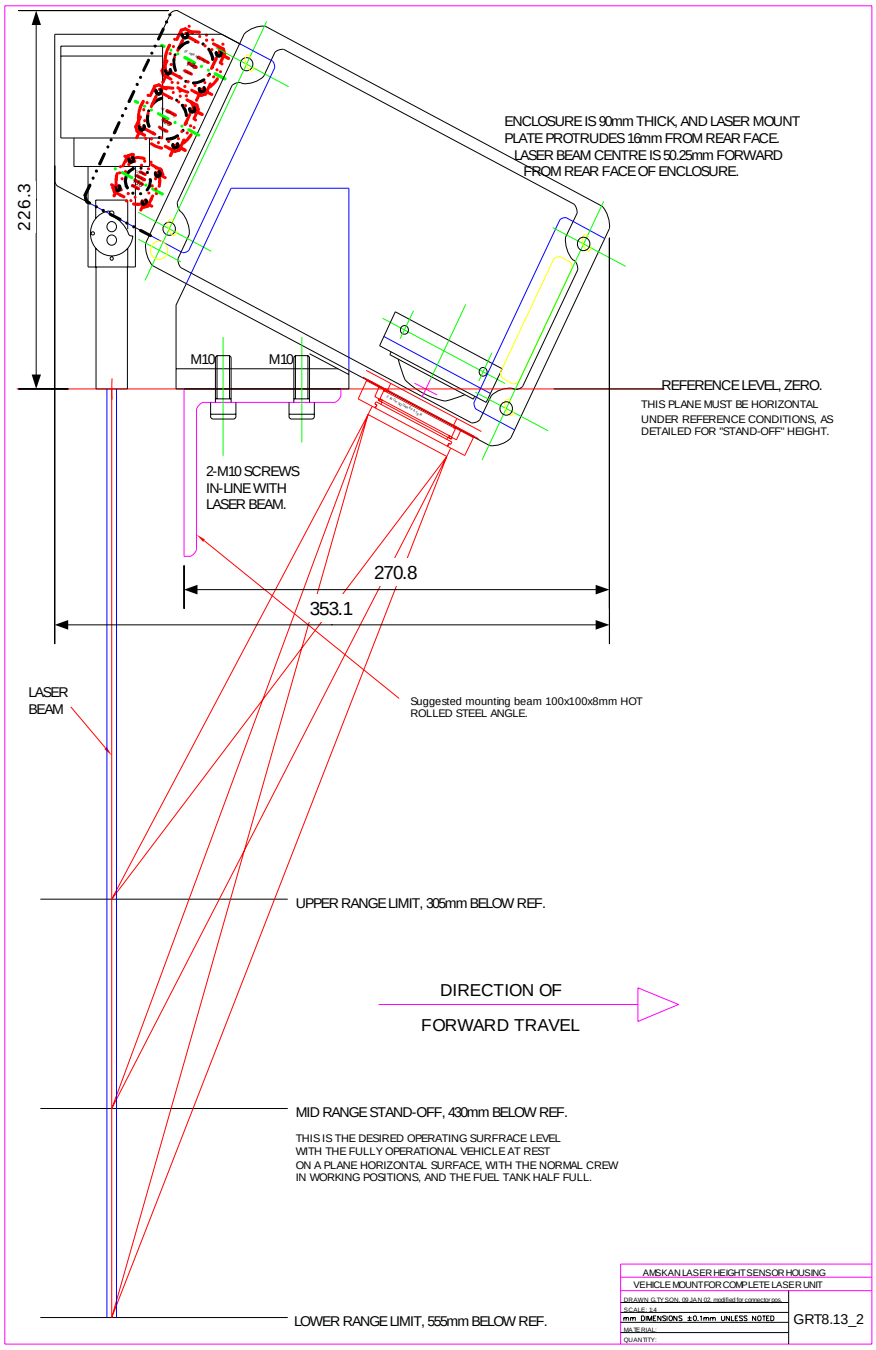
226.3
ENCLOSURE IS 90mm THICK, AND LASER MOUNT PLATE PROTRUDES 16mm FROM REAR FACE. LASER BEAM CENTRE IS 50.25mm FORWARD FROM REAR FACE OF ENCLOSURE.
M10
M10
REFERENCE LEVEL, ZERO.
THIS PLANE MUST BE HORIZONTAL UNDER REFERENCE CONDITIONS, AS DETAILED FOR "STAND-OFF" HEIGHT.
2-M10 SCREWS IN-LINE WITH LASER BEAM.
270.8
353.1
LASER BEAM
Suggested mounting beam 100x100x8mm HOT ROLLED STEEL ANGLE.
UPPER RANGE LIMIT, 305mm BELOW REF.
DIRECTION OF
FORWARD TRAVEL
MID RANGE STAND-OFF, 430mm BELOW REF.
THIS IS THE DESIRED OPERATING SURFRACE LEVEL WITH THE FULLY OPERATIONAL VEHICLE AT REST ON A PLANE HORIZONTAL SURFACE, WITH THE NORMAL CREW IN WORKING POSITIONS, AND THE FUEL TANK HALF FULL.
LOWER RANGE LIMIT, 555mm BELOW REF.
AMSKAN LASER HEIGHT SENSOR HOUSING
VEHICLE MOUNT FOR COMPLETE LASER UNIT
DRAWN: G.TY-SON. 09 JAN 02. modified for connector pos.
SCALE: 1/4
mm. DIMENSIONS ±0.1mm. UNLESS NOTED
MATERIAL:
QUANTITY:
GRT8.13_2

If you require additional stability, you can use the supplied turnbuckles, eyebolts and hooks to attach the ends of the main mounting bar to the vehicle bumper. Attach the eyebolt to the bottom end of the main bar using a single T-Nut as shown in Photo. Attach the hook to the bumper. Adjust the turnbuckle to apply tension to the mounting bar.

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Cable Connections

The Laser DMI Interface has the following Connections

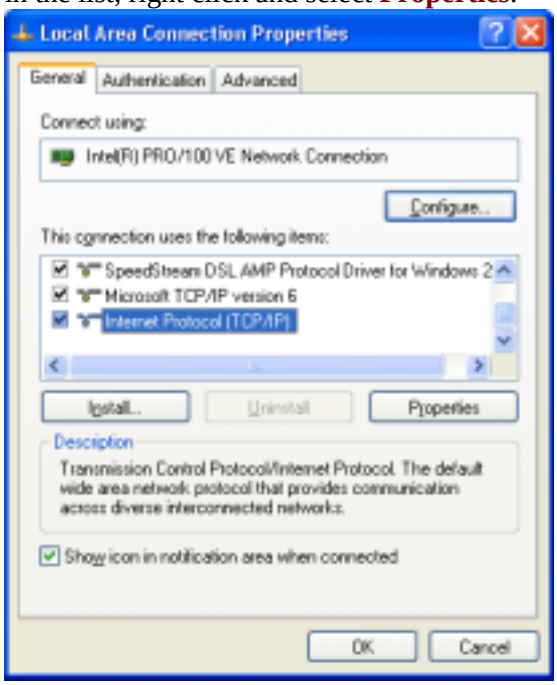
DMI Interface Connection	Connected To
Power	Power Distribution Box
RS 232 Serial	ROMDAS Computer Serial Port*
Laser 1	Laser 1 - 13 Pin Power/Odometry Connector
Laser 2	Laser 2 - 13 Pin Power/Odometry Connector
Encoder	High Resolution DMI
ODO	ROMDAS hardware Interface – ODO
Rev	ROMDAS Hardware Interface – Reverse

Laser Connections	Connected To
Ethernet Connecter 22 Pin circular Connector	Ethernet Switch
Power/Odometry 13 Pin Circular Connector	Laser DMI Laser 1 or Laser 2 Connection
Configuration Serial 7 Pin Circular Connector	Computer Serial port*

* Only need to connect for setup (not needed while surveying)

ROMDAS Server TCP/IP Configuration

The TCP/IP server (i.e. the laptop running ROMDAS) properties can be brought up by **Control Panel|Network Connections** then right clicking on Local Area Connection. Internet Protocol (TCP/IP) should be visible in the list, right click and select **Properties**.



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If the machine is set to get it's IP details automatically from a DHCP server, it will need to be given its own fixed IP address. Click on **Use the following IP Address**. Enter an appropriate IP address and net mask (will depend on local requirements, such as the office network that the machine will have to connect to for data download and retrieval of results). Note the IP address and net mask for use when configuring laser units below.

Laser Profiler Configuration

All laser and accelerometer processors need to have unique unit numbers and IP addresses (with the same net mask). A recommended convention is to provide IP addresses to each unit that end in the same digit as the distinct unit number. The processor unit numbers should be incremental starting from 0, with laser processors as odd unit numbers and accelerometer processors as even unit numbers.
For example in a two Laser Profilometer system
Right WheelPath Laser

- IP Address 172.26.8.240 - Unit Number 0 (Laser),
- IP Address 172.26.8.241 - Unit Number 1 (Accelerometer),

Left WheelPath Laser

- IP Address 172.26.8.242 - Unit Number 2 (Laser),
- IP Address 172.26.8.243 - Unit Number 3(Accelerometer),

These parameters are set on the Laser Profilometer through the serial configuration cable provided. The laser profiler system does not need to have the serial configuration cable connected for normal operation. The serial configuration cable will need to be connected for the following operations;

- Setting the unit up for the first time for use in an Ethernet network, or changing networking conditions.
- Changing the computer within the network that is acting as a data collector (change of destination IP address).
- Calibration of the laser unit (normally a factory operation).
- Diagnostics.

Typically the serial configuration cable can be attached in the field while the unit is mounted on to a vehicle using a portable laptop as a terminal. Tthe cable can be removed without having to power off the system. Always fit the protective cover to the serial configuration cable connector on the profiler when not in use to avoid water and dust ingress.

Use HyperTerminal with 19200N81 settings to communicate with each processor. There will be a delay in characters echoing back from the laser and accelerometer processors until the TCP/IP settings are correct.

Set the **DataCollectorAddress** of each unit to the IP address of the server. The gateway setting is not important, set it to the same IP as the **DataCollectorAddress** setting. Remember to save the configuration settings in each ARL16 unit with the **Save** command, then power off. It is a good idea to check the settings after re-powering on the unit to ensure they are set correctly.

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Profiler DMI Interface Configuration

The Laser DMI Interface has a serial port that is used to set various parameters.

Use HyperTerminal with 19200N81 settings to communicate with the Laser DMI.

When the power is turned on the Laser Interface will display the following message

```
DCL DMI interface v2.1
divisor: 0009
min speed: 0500
```

The Laser DMI uses the following commands:

- 'd' – set divisor factor (Hex)
- 'r' – display current minimum speed and divisor settings (Hex)
- 's' – set minimum speed (Hex)
- 't' – testmode (simulates 81 Km/h)
- 'z' –Finish testmode and zero counter
- ' ' – get current count (Hex)

Note that all numbers are displayed and set in Hexadecimal notation.

When the Laser DMI is in Test mode it simulates a speed of 80km/h. The Min Speed will be exceeded and the Laser will activate if connected. Observe Laser safety when in Test mode.

Profiler DMI Interface Odometer Direction

The Laser Profilometer DMI Interface detects the vehicle direction from the HIGH Resolution DMI encoder. The Reverse LED on the Laser Profilometer DMI Interface and the Reverse Output to the ROMDAS Hardware Interface are activated when the vehicle moves backward. Depending on which side of the vehicle the High Resolution DMI is mounted on the rotation of the encoder in the reverse direction will be different. To allow for mounting on both sides of the vehicle there is a circuit board direction jumper (S1) that will need to be set.

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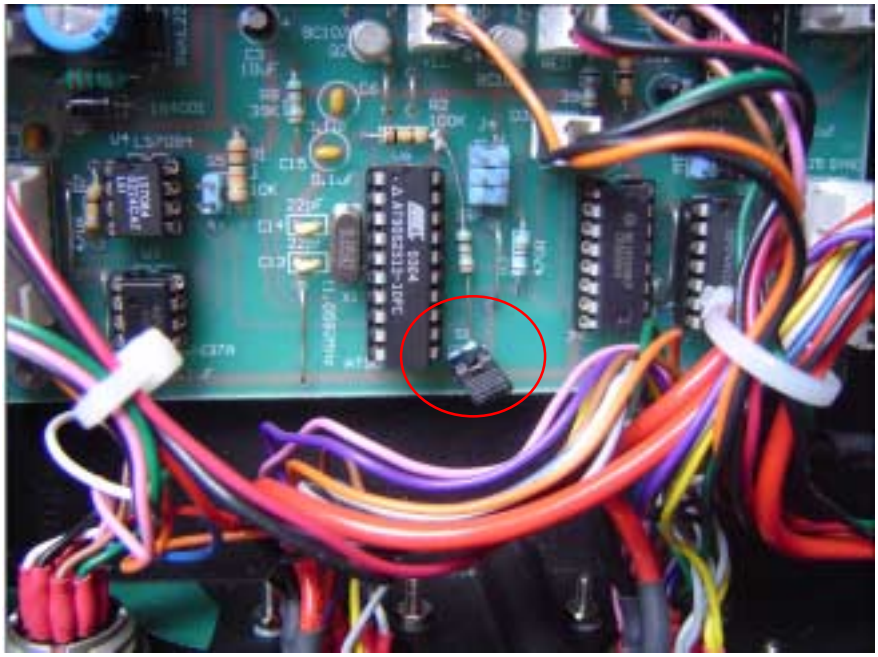
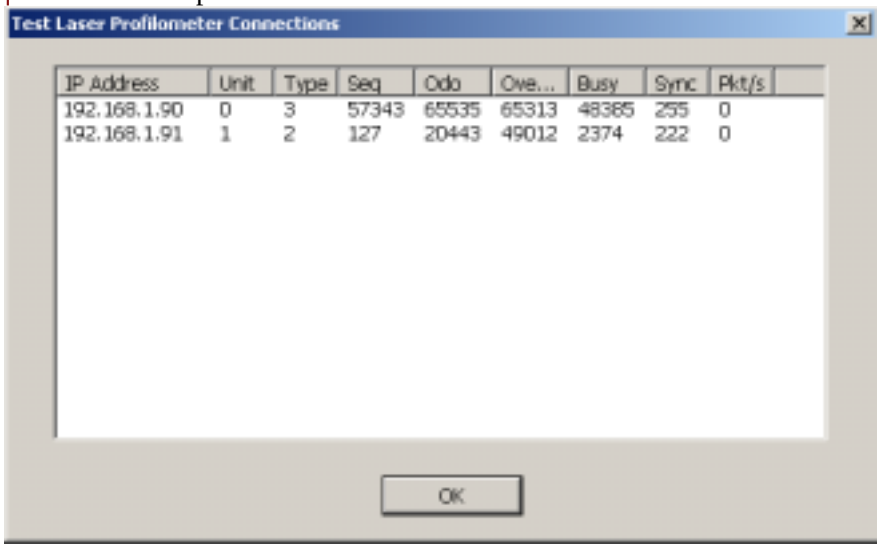


- Jumper ON – High Res DMI installed on left side of vehicle
- Jumper OFF – High Res DMI Installed on right side of vehicle

ROMDAS Profilometer Connections

Check that each processor unit of each profiler is communicating with ROMDAS with the **Setup | Test Instruments | Test Laser Profilometer | Connections** option.



The Laser Profilometer must be powered up only after the ROMDAS software is started for the Laser Profiler Processors to make the IP connection. If there is no IP Address entries in the connections window re-power the Laser Profiler by turning the key on the Laser Profiler DMI Interface Off and On again.

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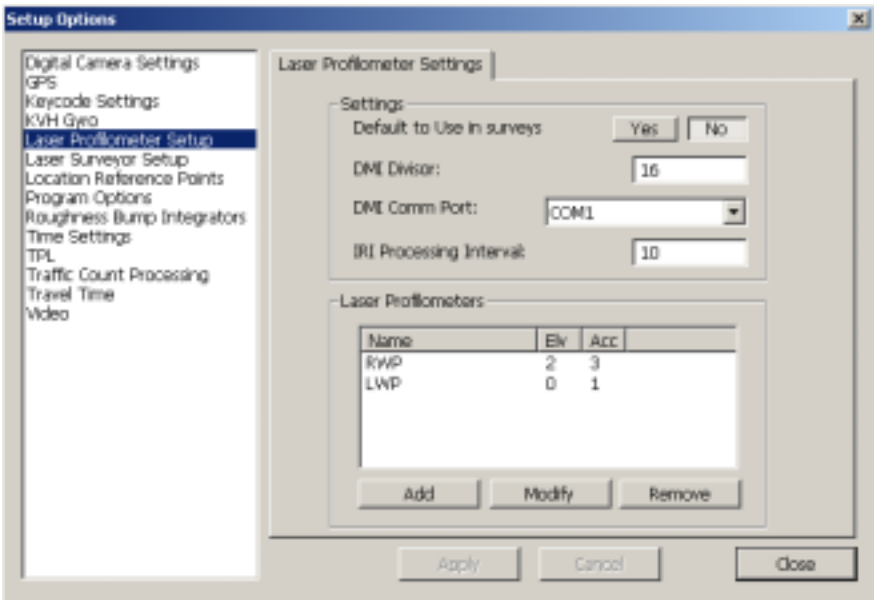
ROMDAS
Profilometer Setup

Once the unit numbers and IP address have been set and the connections with ROMDAS are established through the Connections menu above ROMDAS needs to be configured to recognise each processor unit and each profiler.

Select **Setup | Options | Laser Profilometer Setup**



- **Default to Use in Survey**. Default value for Laser Profiler option in Select devise for Survey check boxes in Survey setup screen.
- **DMI Divisor**. The divisor is used to set the required sampling interval on the laser. This value is calculated automatically as part of the Laser Odometer calibration and therefore will not normally be changed here.
- **DMI Com Port**. The Laser DMI Interface COM port. This COM port only needs to be connected when doing the Laser Bounce and Elevation Test (so the ROMDAS software can put the DMI into TestMode) and during the Laser Odometer Calibration. This COM port does not need to be connected during a survey.
- **IRI Processing Interval**. IRI interval in laser processed tables.

Select **Add** to get dialog below.

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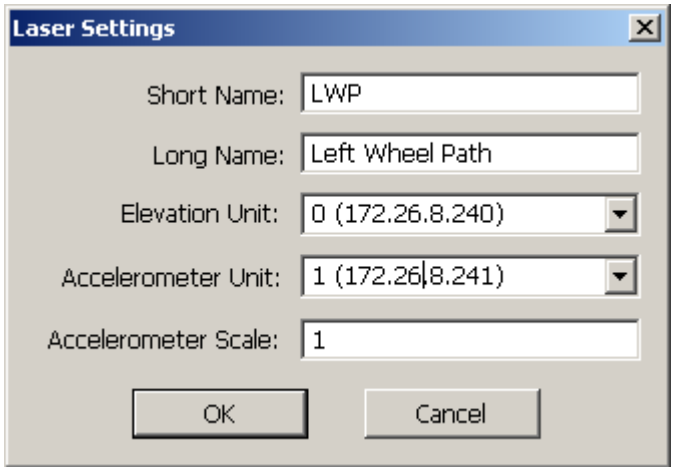

- **Short Name**. This name will be used to identify the laser in the data files and.
- **Long Name**. This name is entered into the ERD file header. It can be a more descriptive name than the Short name above.
- **Elevation Unit**. This is the unique unit number of the Laser processor. The IP address of the unit is also shown for identification
- **Accelerometer Unit**. This is the unique unit number of the accelerometer processor. The IP address of the unit is also shown for identification
- **Accelerometer Scale**. The Accelerometer itself requires no regular calibration, and is a sealed micro-machined servo type unit. Typically this scale factor will be within approximately 5% to 10% of unity, and can be determined using the system bounce testing. Once the amplitude scale factor is determined, it can be applied as a constant multiplier from that point onwards, and should not require adjustment

Calibrating the Laser Profilometer

Calibration Requirements

The Laser requires the following calibrations and calibration checks:

- **Laser Odometer Calibration** This defines the Laser sampling distance and the minimum speed laser safety cut-out.
- **Elevation and Linearity Check.** This measurement checks that the Laser absolute elevation and linearity are within the acceptable limits.
- **Bounce Check.** This measurement checks that all aspects of the Profilometer are working optimally.

Profilometer Odometer Calibration

The Laser Profilometer uses a 7200 pulse per revolution ROMDAS High Resolution DMI connected to the Laser Profilometer DMI Interface. The ROMDAS Interface odometer input is then connected to the Laser Profilometer DMI Interface Odo output. The ROMDAS Interface receives a pulse divided odometer signal.

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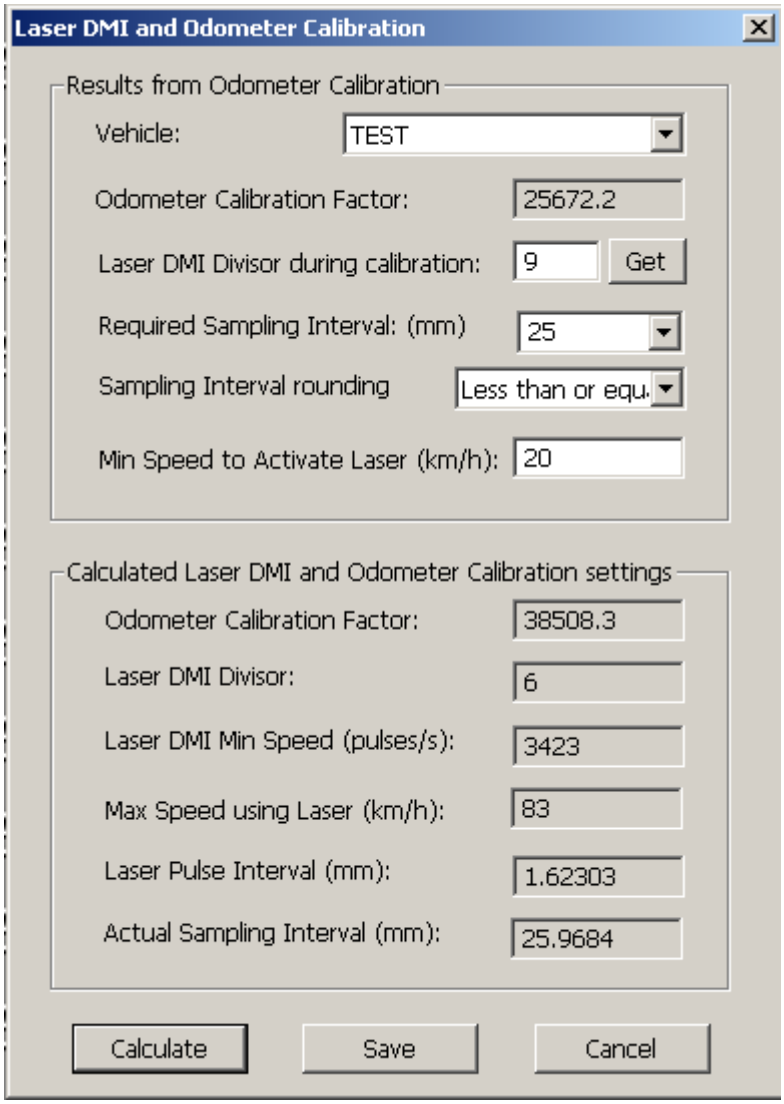
To Calibrate

- Set the Laser DMI Interface Divisor to 10
- Calibrate the Odometer (Section 5.2)
- Ensure that the serial connection to the Laser DMI Interface is connected. Go to **Setup|Calibrate|Calibrate Laser Profilometer** and specify the Com Port



Push **Calculate** and the Laser DMI and Odometer calibration factors are recalculated.

In the example above the **Sampling Interval** was set to 25mm and the **Sampling Interval Rounding** to Less than or equal. This will meet the ASTM E950 94 (Standard Test Method for Measuring the Longitudinal Profile of Travelled Surfaces with an Accelerometer Established Inertial Profiling Reference) requirement of 25mm or less longitudinal sampling interval. This however will restrict the maximum survey speed to 83km/h. Maximum survey speeds of 120km\h are available if the Greater than 37.5mm Sampling Interval is selected.

Select **Save** and the Laser DMI Divisor and Min Speed will be

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automatically set on the Laser DMI (if there is a serial connection). The vehicle Odometer calibration Factor will also be automatically saved if it has changed (this will change if the Laser DMI Divisor has changed).

Elevation and Linearity Test

The most basic test of the laser units is to measure the size of a machined block of known size. A 100mm x 75mm x 50mm test block and reference plate are supplied for this.

> WARNING: Observe Laser Safety when performing all calibration tests. Wear appropriate laser safety eye wear, and ensure that the tests are carried out in a manner safe to pedestrians and other personnel.

It is critical that tests are carried out on a level surface in carefully controlled conditions, as the slightest variation in angle and position of the block will be measured by the instrument.

Using the three separate dimensions of the test block, a total of four height readings can be obtained (including the reference zero). Ensuring that each laser can accurately measure each dimension will confirm the calibration of the laser is sufficient to produce an absolute measurement and also that the laser is linear over the range of the largest dimension.

Once the reference zero has been obtained, place the block under the laser and measure each available dimension. All three dimensions should be reported within ±0.25mm in order for the absolute and linearity test to be passed. Ensure the range of the laser is not exceeded during the test.

If readings within the tolerance band are not obtained, repeat the test in another location. If the laser unit is mounted on a vehicle, during the test ensure that the vehicle is not subject to wind and other disturbances. These can significantly affect the readings of the instrument. Do not get in or out of the vehicle, or even lean on the side of the vehicle during the test as this will affect the readings substantially.

For a system of multiple laser units, repeat the Absolute and Linearity Test on all lasers within the system in turn. If any laser repeatedly reports readings outside the tolerance band, results from that laser unit cannot be used in a survey and the laser unit requires full inspection and calibration by approved personnel.

Go to **Setup|Test Instruments|Test Laser Profilometer|Elevation Tests**

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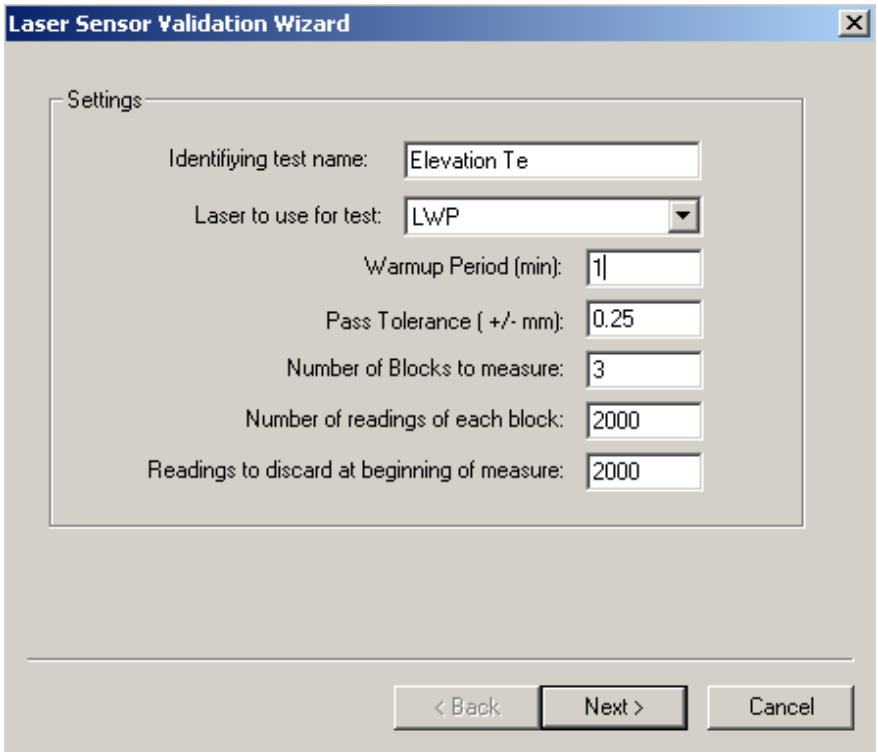

- **Identifying Test Name**. User defined test name. This name will be used in the table names in the laser Calibration.MDB file to identify the test. i.e. Elev_pkt_*identifying test name* and Elev_Data_ *identifying test name*
- **Laser to Use for Test**. Drop down list of available Laser name (shortname). Select the laser to be tested.
- **Warmup Period (min)**. The accelerometer needs several minutes to stabilise. If the laser has just been switched on before the test a warm-up period of 1 minutes should be taken.
- **Pass Tolerance**. The readings for each measurement should be reported within +-0.25 mm in order for the absolute and linearity test to be passed.
- **Number of readings of each Block**. This amount of readings will be taken for each measurement block.
- **Readings to Disregard at Beginning of Measure**. This amount of readings will be disgarded for each measurement block before measurements are recorded.

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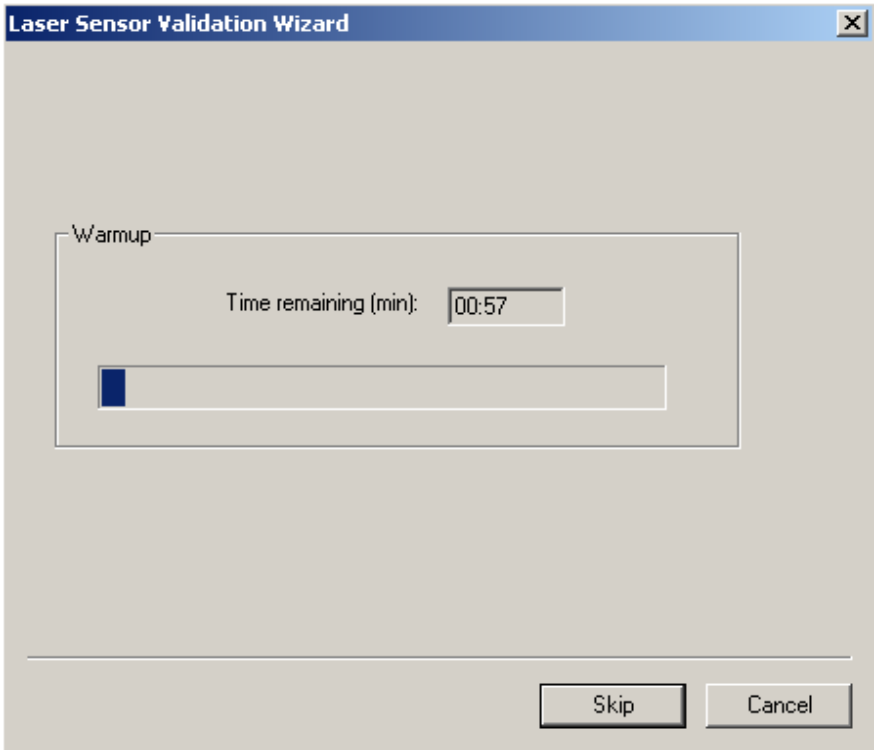

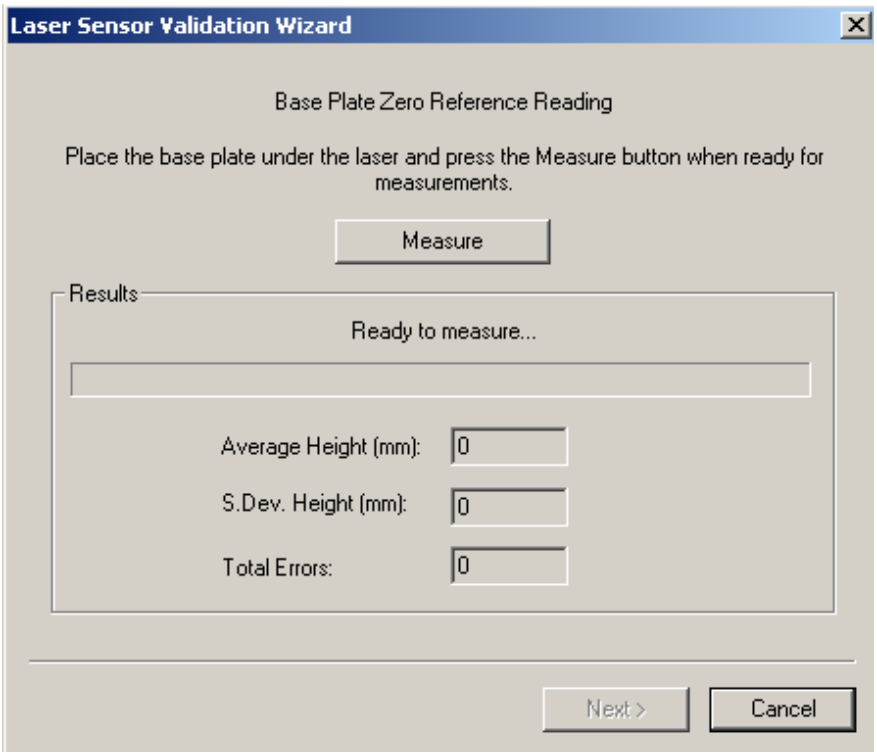

The base plate should be positioned under the laser. This will become the zero reference. Then select **Measure.** The required number of readings will be taken and stored and results displayed.

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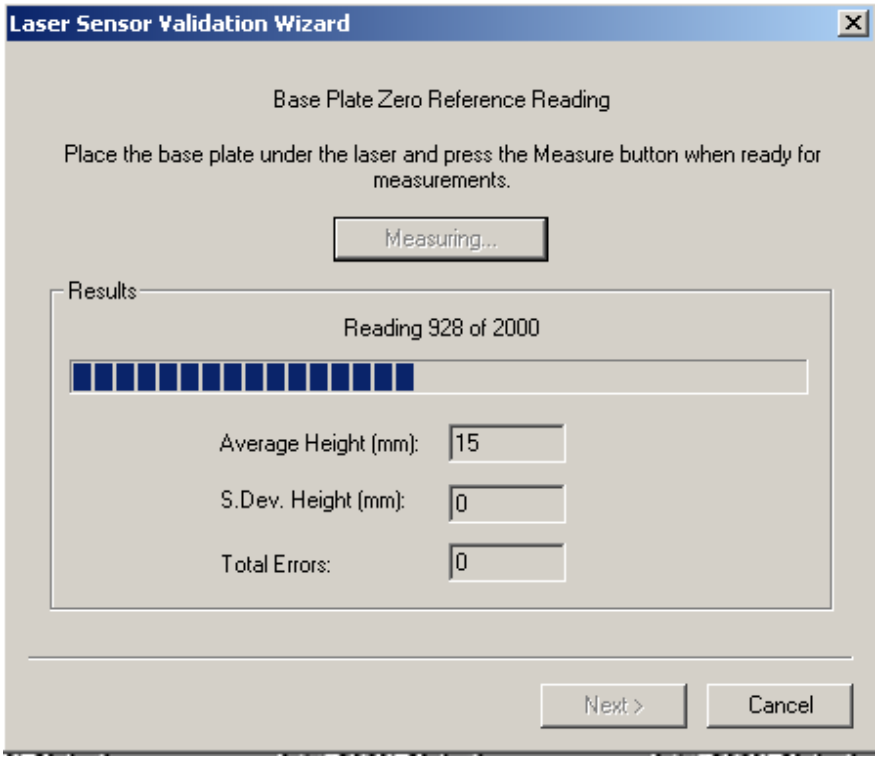
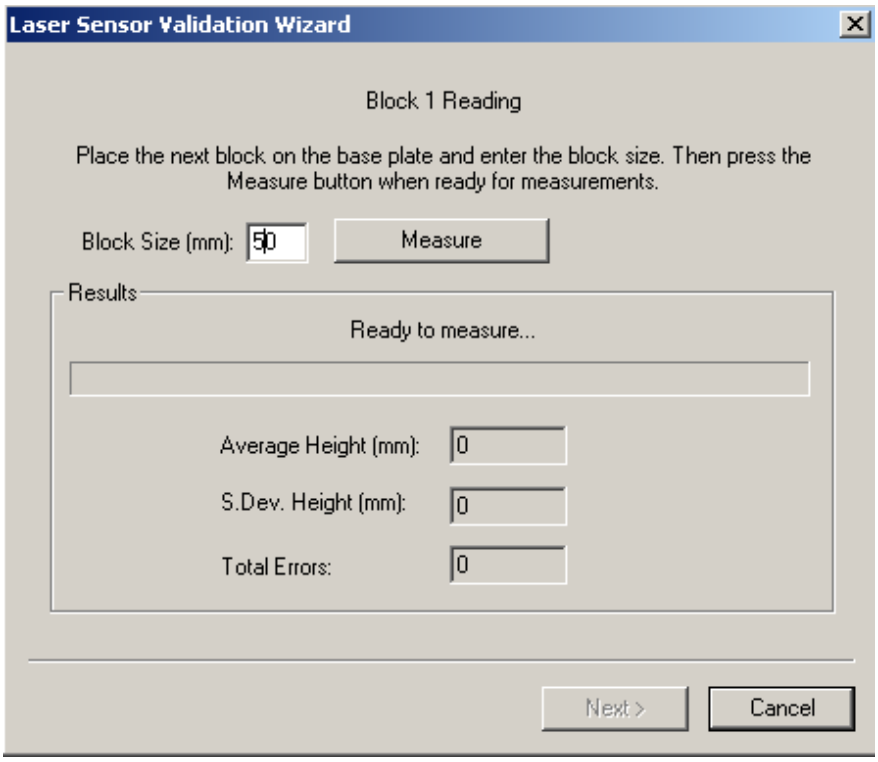

Laser Sensor Validation Wizard
Base Plate Zero Reference Reading
Place the base plate under the laser and press the Measure button when ready for measurements.
Measuring...
Results
Reading 928 of 2000
Average Height (mm): 15
S.Dev. Height (mm): 0
Total Errors: 0
Next >
Cancel

The next block should be positioned on the baseplate and the height of the block entered. Then select **Measure.** The required number of readings will be taken and stored and results displayed.


Laser Sensor Validation Wizard
Block 1 Reading
Place the next block on the base plate and enter the block size. Then press the Measure button when ready for measurements.
Block Size (mm): 50
Measure
Results
Ready to measure...
Average Height (mm): 0
S.Dev. Height (mm): 0
Total Errors: 0
Next >
Cancel

Repeat for the required number of blocks. When finished the results will be displayed as below.

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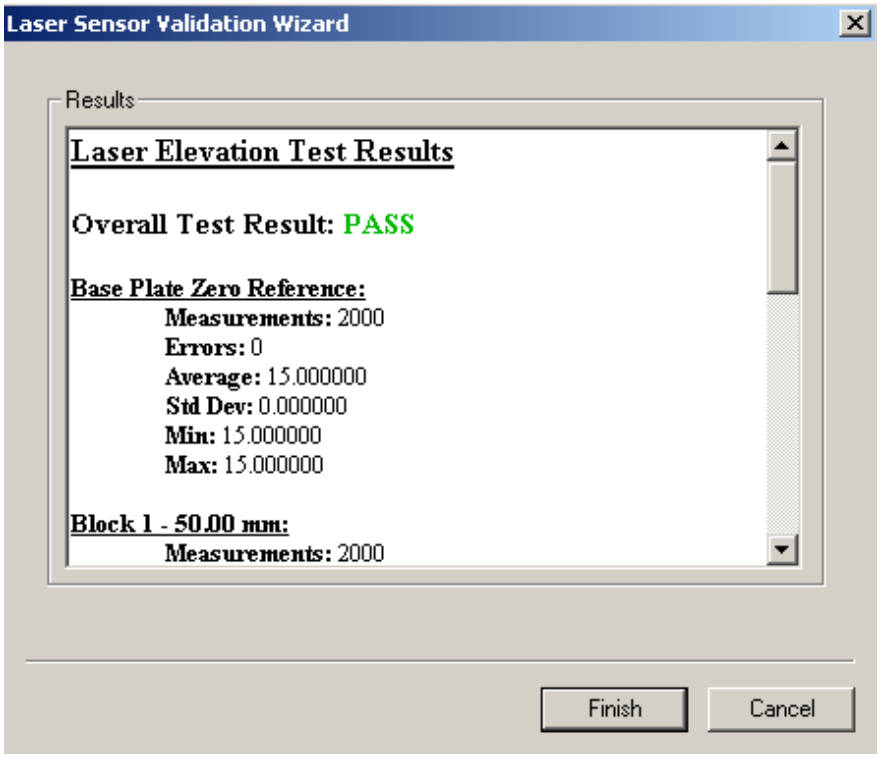
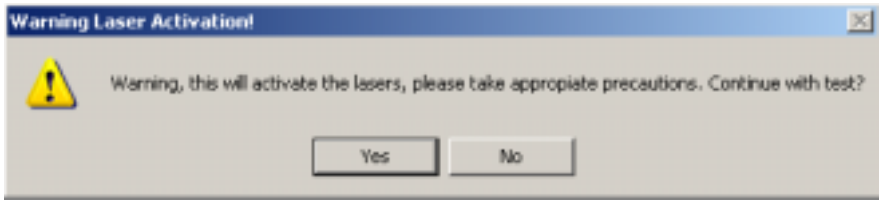


These test results are stored in the Elev_Test_*Testname*.rtf test file in the …\ROMDAS\Calibration folder

Bounce Test

For a system of multiple laser units, repeat the Bounce Test on all lasers within the system in turn. If any laser repeatedly reports readings outside the tolerance band, results from that laser unit cannot be used in a survey and the laser unit requires full inspection and calibration by approved personnel.

Go to **Setup|Test Instruments|Test Laser Profilometer|Dynamic Bounce Tests**


Warning Laser Activation!
Warning, this will activate the lasers, please take appropiate precautions. Continue with test?
Yes
No

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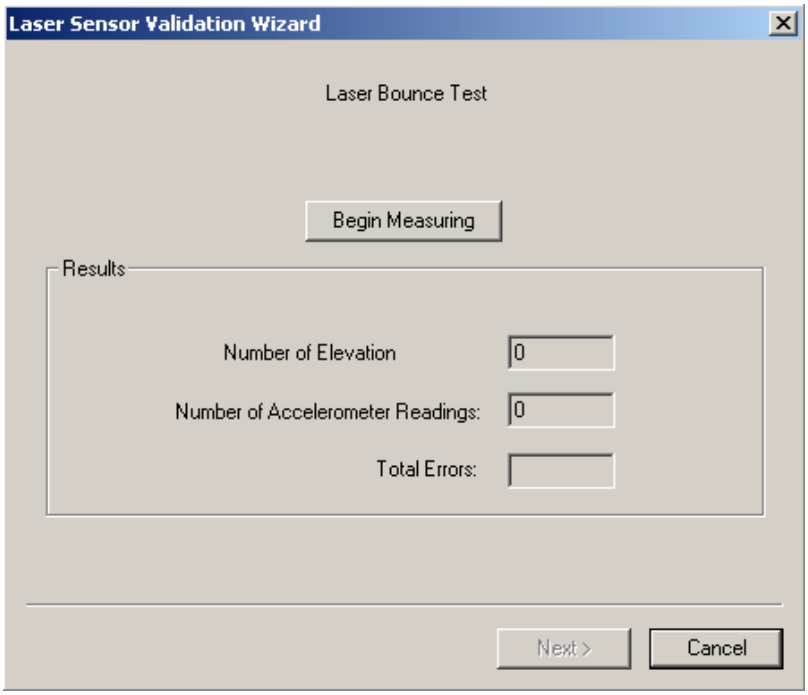
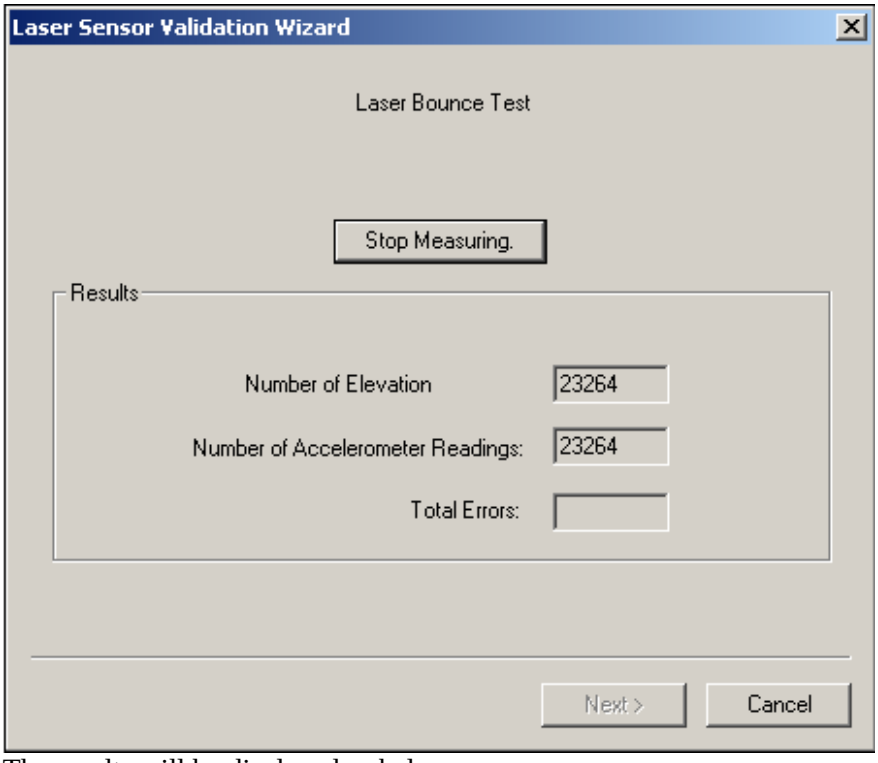


Observing adequate safety precautions have someone “bounce” the vehicle as much as possible. Select the **Begin Measuring** button and when there is 2000 or more **Accelerometer Readings** stop the test.



The results will be displayed as below.

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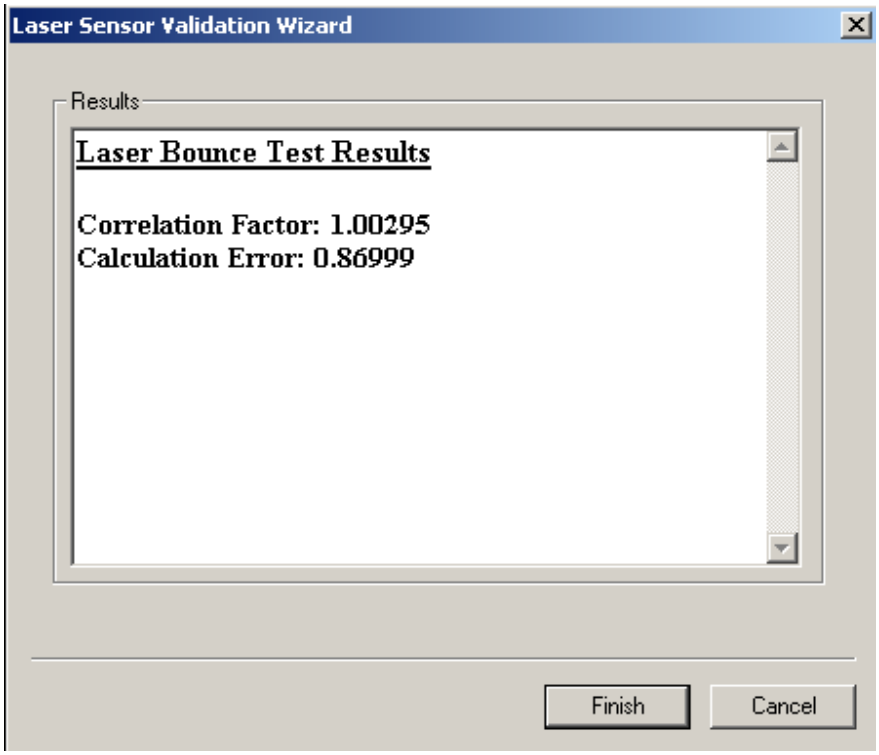

These test results are stored in the Bounce_Test_*Testname*.rtf test file in the …\ROMDAS\Calibration folder. The bounce test data is stored in the Laser Calibration.MDB file in the same folder.

Laser Profilometer Diagnostics and Maintenance

Testing Ethernet Connections

Ethernet Switch Status Lights

The Ethernet switch provides status indicators to inform the user of link presence and link activity. The link presence indicator should show an Ethernet link is present at all times while the Laser unit is powered on. When the unit is receiving odometry pulses and a connection has been established with ROMDAS software, the link activity light should show that data is being transmitted.

PING Command

The standard PING command available on Windows operating systems can be used to test Ethernet connectivity with each profiler unit.

Usage is;
PING <IP address of laser or accelerometer unit>

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```
C:\>ping 192.168.0.1

Pinging 192.168.0.1 with 32 bytes of data:

Reply from 192.168.0.1: bytes=32 time<1ms TTL=128
Reply from 192.168.0.1: bytes=32 time<1ms TTL=128
Reply from 192.168.0.1: bytes=32 time<1ms TTL=128
Reply from 192.168.0.1: bytes=32 time<1ms TTL=128

Ping statistics for 192.168.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

The unit should respond to PING commands immediately as above.

Laser Profilometer Fuse

If there is no response from the Ethernet Connection or the Laser Configuration menu from HyperTerminal the Laser Fuse may have blown.
The fuse is located on the back panel of the profiler housing and should only be replaced by a similar 2.5 Amp fuse.

Laser Lens

The optics within the Laser unit are covered with a standard 52mm clear UV filter used as a protective cover. These should be regularly cleaned with a soft lint free lens cloth, and visually inspected for signs of scratching or damage. As at all times, obey all safety requirements when inspecting or working on the laser units, and ensure the laser shutter is closed. If the protective UV filter is damaged, replacements can be obtained from most photographic stores.

Laser Beam Not Active

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If communications with the laser have been established and data is being received, however the Laser unit is reporting a constant laser elevation value regardless of target distance, then the unit may not be lasing. The presence of the invisible laser spot can be established using IR sensitive test cards available from photonics suppliers. Check that the physical beam shutter is open and that the laser safety electrical interlock Activate signal is present (indicated by the Minimum Speed Exceeded LED being ON).
Always ensure adequate safety procedures are followed at all times when using or diagnosing faults with the Laser units

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Appendix D: Installing and Calibrating the Transverse Profile Logger

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Overview

TPL System

The ROMDAS Transverse Profile Logger (TPL) consists of a series of ultrasonic sensors contained in a 'housing' which is affixed to the front of the vehicle. The sensors emit ultra-sound pulses and the distance of each sensor from the pavement is established from the time it takes for the pulse to travel to and from the pavement.

The TPL sensors are contained in ultrasonic measurement sensor arrays (UMSA) or nodes. These consist of 5 sensors in an aluminium housing. The nodes are fired sequentially and the data is stored on the computer for analysis.

This Appendix

This appendix describes the installation and calibration of the TPL, as well as additional background information which may be of interest to users.

Installing the TPL

TPL Nodes

The TPL is supplied either as the electronics only or as the electronics plus enclosure. If you have purchased the electronics only it will be necessary to fabricate your own TPL housing. This can be fabricated from metal or very strong wood. The only requirement is that holes be drilled to match the bolts on the nodes and that these be spaced with 100 mm between adjacent nodes. Once completed, the installation is the same as described below.

The ROMDAS TPL bar is fabricated from aluminium and comes with the node mounting holes pre drilled. The nodes are labelled with the Node number (1 to 6) and the sensor numbers (1 to 30). Before installing the bar on the vehicle ensure that the node numbers are increasing sequentially from the kerb side of the vehicle to the centreline side, and that the numbers are also increasing sequentially as well. This is illustrated in Figure C.1.

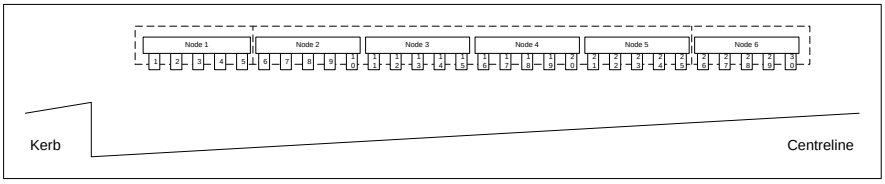

Figure C.1: Node Installation Order

Connections

At the end of each node there is a cable. The nodes are connected sequentially to each other in a continuous 'chain'. The cable at the end of Node 1, Sensor 1 is connected to the 'Master Controller' which should be installed in the vehicle.

NOTE: The cable connecting the TPL to the Master Controller must be kept clear of any high tension leads in the vehicle.

Attaching the TPL to the Vehicle

The ROMDAS TPL enclosure consists of a main 2 m section with two 500 mm 'wings'. The wings are removable/retractable.

The enclosure **MUST** be mounted at a height of 250-300 mm above the pavement surface. If the sensors are outside of this range problems with the readings may arise on certain pavements.

The enclosure comes with two mounting brackets. These need to be attached to the vehicle, preferably by welding. An extension bracket may be required to ensure that it is offset sufficiently from the vehicle.

NOTE: The mounts should be regularly checked to ensure that they have not cracked or been weakened by the combination of vibrations and the weight of the TPL. There is always a possibility of failure which would see the TPL fall off the vehicle. **DCL bears no responsibility for damage due to mounting failure.**

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Calibration

Calibration Requirements

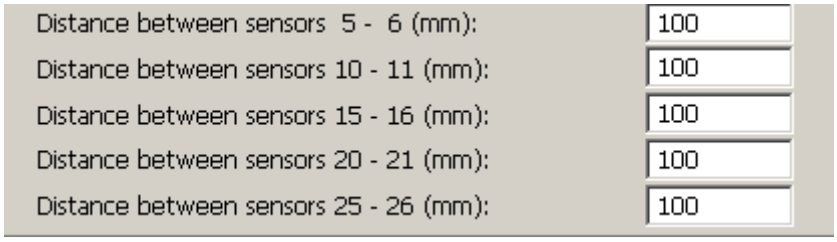
The TPL requires the following calibrations:

- **Spacing of Nodes in TPL Housing.** This defines the distances between the nodes in the housing.
- **Distance Calibration.** This calibrates the measurement distances of the ultrasonic sensors.
- **Create Datum Level.** This corrects for differences in the elevations between adjacent sensors.

Before each major survey the **Survey Calibration** needs to be done. This sees the measurements of the sensors checked to confirm that they are within tolerance and levels the readings for differences between adjacent sensors. This is described in Section 5.5.

Node Spacing in TPL Housing

The TPL housing supplied by DCL is designed so that all the nodes are at 100 mm spacings. If the TPL enclosure has not been supplied by DCL, the spacings of the sensors between nodes should be measured and, if not 100 mm, the measured values entered under **Setup|Options|TPL**.


Distance between sensors 5 - 6 (mm): 100
Distance between sensors 10 - 11 (mm): 100
Distance between sensors 15 - 16 (mm): 100
Distance between sensors 20 - 21 (mm): 100
Distance between sensors 25 - 26 (mm): 100

Distance Calibration

The distance calibration is done to ensure that the TPL measurements correspond to a known distance. A calibration equation is developed which predicts the distance (in mm) as a function of the TPL raw measurements.

NOTE: This calibration is done by DCL using special equipment prior to the TPL being shipped and the TPL should include the calibration equation for the TPL.

Equipment

- tape measure
- an object with a vertical face (e.g. 3.5” plastic floppy disk box)

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Preliminary Setup

NOTE: It is only necessary to do this anaylsis for one sensor, although it may be repeated for multiple sensors and the results averaged..

1. Set up one of the TPL USMA sensors along with the fixed sensor and connect to the TPL Master Controller and notebook computer.
2. Select **SETUP|CALIBRATE|CALIBRATE TPL|CREATE CALIBRATION DATA**.
3. Enter a description of the calibration test and the file name.
4. Start the sensor recording.

Measurement Data

1. Place the tape measure perpendicular to one of the UMS transducers with the 0 value at the edge of the UMS.
2. Place the object at a distance of approximately 250 mm on the tape.
3. Note the distance displayed on the notebook and the distance of the fixed sensor and record on Form 1. Also enter the actual distance (it is not necessary to be exactly 250 mm).
4. Move the object to 275 mm on the tape and note the distances.
5. Repeat step 4 every 25 mm until 500 mm of data have been collected.

NOTE: There must be only a single value for the standard conditions for all measurements.

Develop Regression Equation

1. Open the Excel template **TPL Calibration.xlt**.
2. On the tab labelled **Distance Data** enter the measurement data.
3. Open the tab **Validation Summary.**
4. Right click on the plotted series and select **Add Trendline**.
5. Ensure that the trendline is linear.
6. Under options select **Display Equation on Chart** and **Display R-squared on Chart** (see below).

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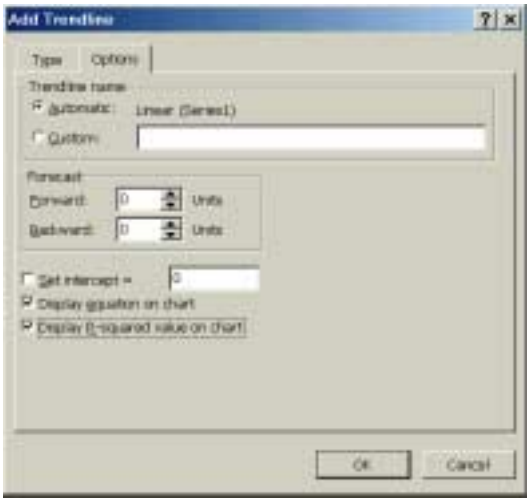
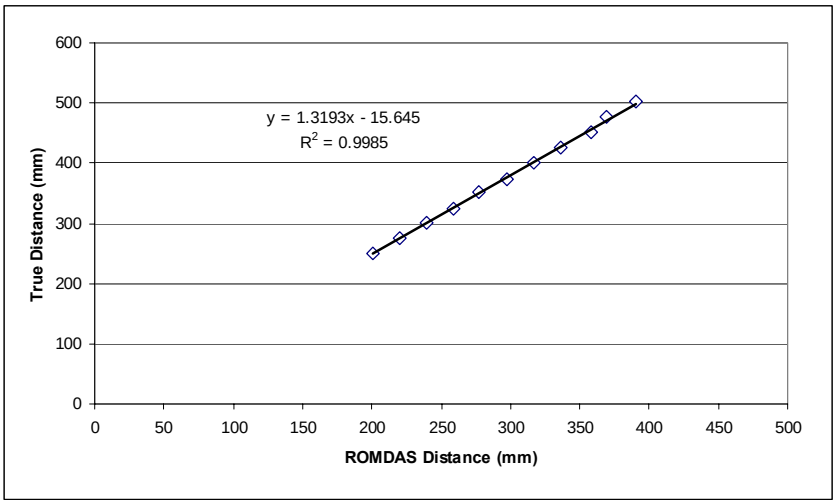


7. Select **OK** and the regression line will be fitted (see below).



8. Record the values for the constant and slope on the form.
9. Record the value for the standard conditions on the form.

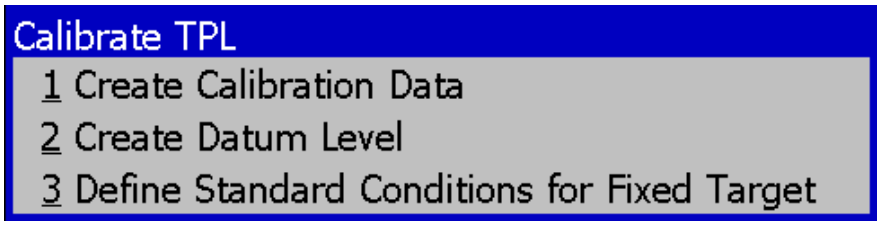
Enter the values for the constant and the slope under **SETUP|OPTIONS|TPL** TPL Measurement Calibration Coefficients.

Create Datum Level

The Datum level is used to correct for differences in the elevations between sensors.

Equipment

- ROMDAS vehicle with TPL operating and computer installed
- TPL test trough. This can be made from a wooden frame with plastic sheeting, as shown below.



- Fill the TPL trough with water
- Park the vehicle with TPL mounted over the trough on the level concrete floor of the garage
- Bounce the suspension of the vehicle to settle the suspension

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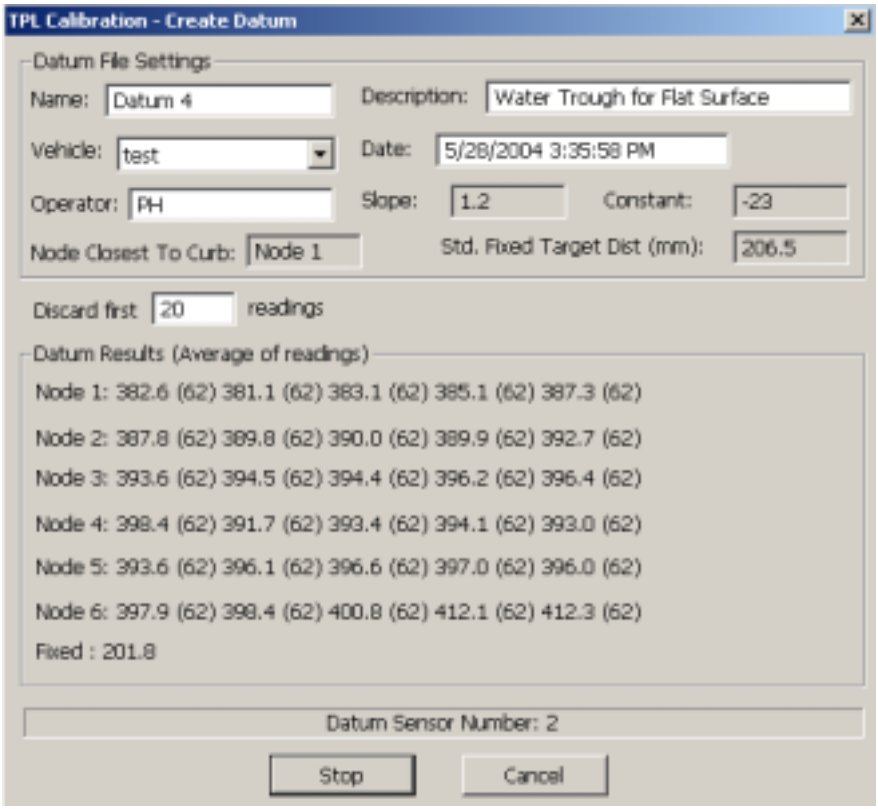
TPL Calibration - Create Datum
Datum File Settings
Name: Datum 4
Description: Water Trough for Flat Surface
Vehicle: test
Date: 5/28/2004 3:35:58 PM
Operator: PH
Slope: 1.2
Constant: -23
Node Closest To Curb: Node 1
Std. Fixed Target Dist (mm): 206.5
Discard first 20 readings
Datum Results (Average of readings)
Node 1: 382.6 (62) 381.1 (62) 383.1 (62) 385.1 (62) 387.3 (62)
Node 2: 387.8 (62) 389.8 (62) 390.0 (62) 389.9 (62) 392.7 (62)
Node 3: 393.6 (62) 394.5 (62) 394.4 (62) 396.2 (62) 396.4 (62)
Node 4: 398.4 (62) 391.7 (62) 393.4 (62) 394.1 (62) 393.0 (62)
Node 5: 393.6 (62) 396.1 (62) 396.6 (62) 397.0 (62) 396.0 (62)
Node 6: 397.9 (62) 398.4 (62) 400.8 (62) 412.1 (62) 412.3 (62)
Fixed : 201.8
Datum Sensor Number: 2
Stop
Cancel

- Select **Setup|Calibrate|Calibrate TPL|CREATE Datum Level**
- Enter Test name and other details
- It is recommended to discard the first 20 readings so that the fixed sensor settles down with consistent readings
- Run the TPL for approximately 1 minute

For each sensor the average value of the readings is displayed as well as the total number of readings. The datum sensor in the above example is sensor 2 as it has the value that is closest to the surface (i.e. lowest value). The datum file will contain the measurements of all other sensors relative to sensor 2.

The datum data is stored in the …\ROMDAS\Calibration\TPL Calibration.mdb file in the datum table.

Sensor Numbering

The TPL sensors must be numbered sequentially (1 to 30) across the TPL housing. If this is not done the software will incorrectly calculate the rut depth. If any nodes are removed from the housing or node numbers swapped for any reason the sensors need to be checked to ensure that the numbering is sequential.

Ensure Sequential Numbering

Ensure that the sensor nodes are correctly ordered from 1 to 6 (*i.e.* 1-2-3-4-5-6 not, for example, 1-3-2-4-5-6). This is done by starting **Setup|Test Instruments | Test TPL** and having an assistant place their hand under each of the sensors. The values displayed for each covered sensor will change and it can be confirmed that they are in the correct order.

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Node closest to Curb

The Node closest to Curb option needs to be set. If this is not done the software will incorrectly report the rutting in the centre and edge wheelpaths. Different countries drive on different sides of the road. However your TPL will usually come with the Node 1 on the right hand side of the vehicle[30]. This means that Node 1 will be closest to the curb side of the road on left hand drive vehicles.

TPL Diagnostics

Overview

The TPL Logger has various setup routines under **Setup|Options|TPL** .

Setting Node Number

Each USMA node has its own unique node number (1-6) The nodes are mounted sequentially in the TPL housing. Therefore no UMSA node can be interchanged with another without first resetting the Node number This needs to be done when you are in the field and a sensor fails. The steps in involved are as follows:

1. The TPL node number reset button is installed on the board in the early units, and is at the side in later units. The side mounted buttons are accessed by taking off an end plate and locating the button. With earlier units, you must open up the node and **CAREFULLY** remove the board. It is necessary to remove the end plates from both ends and pull the board out from the end with the circuits on top.
2. Connect the node to the Master Controller.
3. Run ROMDAS .
4. While the Node button is depressed select SET NODE NUMBER enter the new node number (1 to 6).
6. Test that the sensor has been assigned the correct node by running the ROMDAS measurement option.

This option is used to set the node number of each UMSA node. The numbering is as shown below. The node is set by plugging the array directly into the computer and then redefining the number.

[30] After 2003 all TPL's will be shipped with Node 1 to right of vehicle, prior to 2003 this was altered to suit the specific country shipped to.

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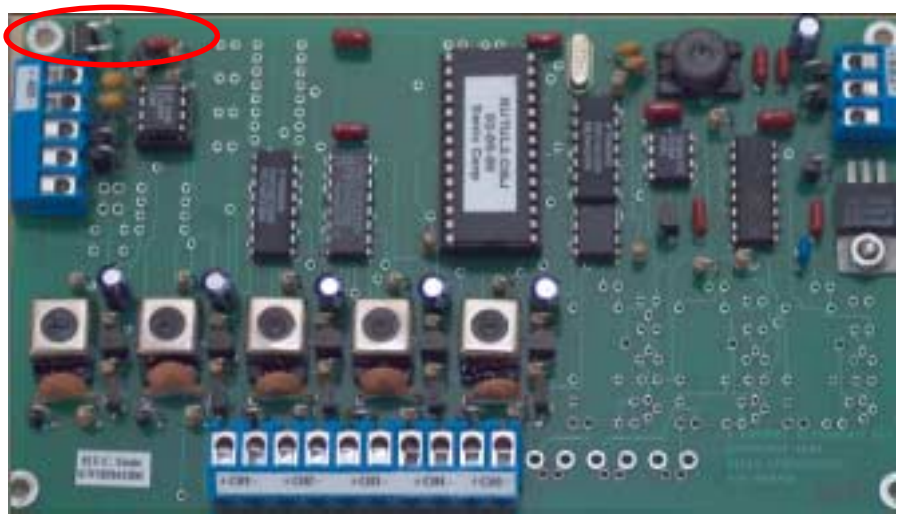

From late 1999 this button is located on the side of the board so is accessible by simply removing the end plate.

Gain Set

Nodes

The gain dictates the sensitivity of the ultrasonics sensors. The values range from 5 to 30 with the higher the number the higher the sensitivity. The gain is set by defining both the node and the gain.

Fixed Distance Sensor

The gain setting on the fixed distance sensor is adjusted by first removing the electronics unit from the tube. These are held in place by silicon so one simply needs to twist and gently pull the end with the cable from the tube. There is a small white one turn potentiometer on the circuit board. Turning this pot counterclockwise reduces the sensitivity and turning it clockwise increases the sensitivity. It is a one-turn pot. If the sensitivity is too low then the fixed target will not be seen. If the sensitivity is too high then the sensor will give unstable readings. The distance measurement may jump around a bit. The setting is therefore established through a process of trial and error.

It is necessary to run ROMDAS with the TPL calibration mode (**SETUP|CALIBRATE|CALIBRATE TPL|CREATE CALIBRATION DATA**) to confirm the setting and once the fixed distance sensor reading is stable the appropriate gain has been established.

Communication Protocols

The nodes are triggered by sending the following ASCII characters from the computer. All communications are at 19200 baud 8 data bits, 2 stop bits no parity:

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"M" - Measure

Instructs system to return 30 measurements. This is used for setting the TPL up and debugging. The nodes return 64 bytes of data. The first 2 bytes returned are 00H. The third byte is the LSB byte of the distance measurement for the first nodes first sensor (from passenger side). The fourth byte is the MSB byte of the distance measurement for the first nodes first sensor. The next 58 bytes contain the same data for the next 29 sensors across the TPL. After the data a 2 byte checksum is sent which is the sum of the entire data set (first 62 bytes).

These 2 bytes are converted to a 16 bit binary number. The sensor measurements are converted to the distance to the ground from the ultrasonic transducer face using a factor of 0.0429768 mm/count or 0.001692 inches/count.

"R" - Reset

Instructs system to reset a data pointer to the beginning of the stored data in preparation for downloading data.

"D" - Download

Instructs the system to download 64 bytes of data and increment data pointer. The data structure is identical to the "M" command above.

"N" - Node Address Set

A 2 byte command that allows setting the node number of a node. The first byte is the "N" character and the second byte is a binary number from 1 to 6 that sets the node address of one of the ultrasonic modules. If this command is received by a module and its node set push button is depressed, the module will take the node number as its own. The master controller returns an "ACK" if any node takes this address. The master returns a 01H if there is no response from the nodes.

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Appendix E: Installing the Video System

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Overview of ROMDAS Video System

Video Systems

The ROMDAS video system is consists of a camera in an environmentally protected enclosure which is mounted on the outside of the vehicle and one of five options for recording the video data and they differ both by how the image is captured and where it is stored: either as a directly digitised computer file or on a video tape.

System	Abbreviation	Direct Digitising	Video Tape
Firewire Camera System	FCS	Yes	No
Fireware Analog System	FAS	Yes	Yes/No
Analog Recording System	ARS	No	Yes
Analog Digitising System	ADS	Yes	No
Analog Digitising and Recording	ADR	Yes	Yes

The Firewire (IEEE-1394) systems only work with ROMDAS for Windows, while the other systems work with all versions of ROMDAS.

Overlay of Data

During video recording the video data have key data superimposed on the image. The data can be defined by the user, but typically consists of:

- Road name and description;
- Location (distance and GPS co-ordinates);
- Roughness; and,
- Keyboard events.

When recording to a video tape or using a ROMDAS DOS system, these data are mixed with the video signal using a hardware character overlay device. With Firewire and ROMDAS for Windows direct digitising the overlay is generated internally using Direct-X.

Setting Up the Video Camera

Components

The video camera is supplied with the following components:

- Firewire or analog video camera
- Environmentally protected housing for camera
- 12v Power supply and remote for camera (analog only)
- Camera control cable
- Camera power cable (analog only)
- Power distribution box and cables
- Base plate for mounting enclosure to roof rack
- Screws for closing enclosure access panel
- Bolts for attaching base plate to roof rack
- Sun shroud and screws for attaching sun shroud to base plate

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The first step requires that the video camera be properly set up for remote use (*ie* for using once it is sealed in the enclosure). Once this is done, the camera is installed in the enclosure.

Configuring Analog Cameras

The key configurations required for the cameras generally consist of:

- **Auto Focus**: This is **DISABLED** otherwise the image from the moving vehicle will fade in and out of focus as it tries to focus on passing objects.
- **Shutter Speed**: The shutter speed should be set to a high rate

The following gives the settings for some commonly supplied cameras:

Sony TRV-120E	
Date or time showing on video (pg 71, 94, 101 and 102)	Turn this off using the menu setting
Steady Shot (pg 88 and 89)	The Steady Shot should be turned ON to compensate for camera-shake.
Manual Focus (pg 58 and 59)	It is recommended that the camera be set to manual focus either on the road at a fixed distance in front of the vehicle or to infinity. You do this by setting the Focus button to manual and turning the focus dial on the front of the camera. If using autofocus, ensure that the image is set on INFINITEY. This will see the following image displayed:
Shutter Speed (pg 57)	You cannot control the shutter speed on this camera. It is recommended that the Auto Exposure function be set to 'Sports lesson mode' since this minimises shake on fast-moving subjects. When this is done the camera will show this image:

Sony TRV-110E	
Date or time showing on video (pg 35 and 79)	Turn this off using the menu setting
Steady Shot (pg 80)	The Steady Shot should be turned ON to compensate for camera-shake.
Manual Focus (pg 58)	It is recommended that the camera be set to manual focus either on the road at a fixed distance in front of the vehicle or to infinity. You do this by setting the Focus button to manual and turning the focus dial on the front of the camera. If using autofocus, ensure that the image is set on INFINITEY. This will see the following image displayed:

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Shutter Speed (pg 54)	You cannot control the shutter speed on this camera. It is recommended that the Auto Exposure function be set to 'Sports lesson mode' since this minimises shake on fast-moving subjects. When this is done the camera will show this image:

Sony TRV-3400E	
Date or time showing on video (pg 35)	Turn this off by pressing the Date and/or Time buttons on the side of the camera.
Steady Shot (pg 59)	The Steady Shot should be turned ON to compensate for camera-shake.
Manual Focus (pg 62)	Under some circumstances you may like to set the focus to manual and focus either on the road at a fixed distance in front of the vehicle or to infinity. You do this by setting the Focus button to manual and turning the focus dial on the front of the camera.
Shutter Speed (pg 66)	The shutter speed should usually be set to around 1/300. If the power is completely disconnected from the camera the shutter speed will need to be reset.

Configuring Firewire Cameras

Sony TRV70 Camera

The camera supplied with The ROMDAS Digital Video system is capable of producing exceptionally high quality digital Videolog images. In order to achieve the highest quality images for this application, we recommend that you change some of the default settings of the camera. All of these settings are discussed in more detail in the manual supplied with camera. These instructions are intended as a quick start guide to optimal settings for Videolog applications.

For best performance, camera settings should be reviewed at the beginning of each run and adjusted to match the current conditions. For example, if you must change direction away from the sun to into the sun, you should check the **Back Light** setting, and if lighting conditions change substantially you should check the **Automatic Exposure** setting. In all conditions, we recommend that you use the **Progressive Recording Mode**.

For the Sony TRV70 camera we recommend the following changes to the default camera settings.

1. PROGRESSIVE RECORDING

The first change is to put the camera into **Progressive Recording Mode**. We recommend that this setting be used for all videolog applications. In this mode, all of the image pixels in a capture frame are captured at the same instant in time. This mode eliminates the jaggy lines seen in many images captured from common video cameras that capture the image pixels in interlaced mode (at two different times). To set the camera for **Progressive**

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Recording Mode please follow these steps:

1. Set the Power Switch on the camera to **CAMERA**
2. Using the LCD Touch Panel press **FN** and select **PAGE3**
3. Using the LCD Touch Panel press **PROGE REC**
4. Using the LCD Touch Panel press **EXIT**

When the camera is turned on, the LCD display panel should now display **PROGR.REC**
if not, please repeat the above steps.

2. AUTOMATIC EXPOSURE

The next change is to select an **Automatic Exposure** setting. The setting you choose depends on the general lighting conditions and the direction the direction the camera is pointed. Select one of the following exposure settings depending on conditions.

2.1 Bright Sky Conditions

For general video logging applications where you have bright skies with little cloud cover, you should select the **BEACH&SKI** setting. To make this setting please follow these steps

1. Set the Power switch to **CAMERA**
2. Using the LCD Touch Panel press **FN** to display **PAGE1**
3. Using the LCD Touch Panel press **MENU**
4. Select **PROGRAME AE**, and press **EXEC** **EXEC**
5. Select **BEACH&SKI** (using arrow keys) and press **EXEC**
6. Press **EXIT**

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When the camera is turned on, the LCD panel should now display a small **palm tree** icon in the lower left corner. If not, please repeat the above steps.

2.2 Overcast Sky Conditions

For general video logger applications where you have dark or heavily overcast skies, you should select the **LANDSCAPE** setting. To make this setting please follow these steps

1 Set the Power Switch to **CAMERA**

2 Using the LCD Touch Panel press **FN** to display **PAGE1**

3 Using the LCD Touch Panel press **MENU**

4 Select **PROGRAME AE**, and press **EXEC** **EXEC**

5 Select **LANDSCAPE** and press **EXEC**

6 Press **EXIT**

When the camera is turned on, the LCD panel should now display a small **mountain** icon in the lower left corner. If not, please repeat the above steps.

2.3 Pavement Video

If you are more interested in focusing the camera on the pavement, and have very little or no bright sky appearing in the video image, then you should change the Automatic Exposure setting to SPORTS. To make this setting please follow these steps

1 Set the Power Switch to **CAMERA**

2 Using the LCD Touch Panel press **FN** to display **PAGE1**

3 Using the LCD Touch Panel press **MENU**

4 Select **PROGRAME AE**, and press **EXEC** **EXEC**

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5 Select **SPORTS** and press **EXEC**

6 Press **EXIT**

When the camera is turned on, the LCD panel should now display a small **golfer** icon in the lower left corner. If not, please repeat the above steps.

3. Back Lighting

You should always try to avoid capturing video while driving into the sun. This is because the camera will tend to under expose images when facing into the sun. This is just the same as when taking pictures with any still camera. In conditions where you have no alternative but to drive into the sun, you can reduce the under exposure effect by using a special setting called **Back Light**. The Back Light setting operates independently of the Auto Exposure settings. To make this setting, please follow these steps

1 Set the Power Switch to **CAMERA**

2 Press the **BACK LIGHT** button located on the front-left lens section of the camera

When the camera is turned on, the LCD panel should now display a small sun icon in the lower left corner. If not, please repeat the above steps.

The Back Light feature can be turned off by pressing the BACK LIGHT button a second time.

4. FOCUS

By default, the camera is in Auto Focus mode and will continually attempt to adjust the lens focus so that the central part of the frame is in focus. In video logging applications, this could result in the focus shifting when approaching another vehicle or other objects in the centre of view. If you do not want the focus to behave this way, you can turn off the auto focus feature by pressing the **FOCUS** button on the front-left lens section of the camera. When auto focus has been turned off, you can then turn the lens focus ring to select a fixed focus distance. When you are manually focusing the camera, the focus distance is displayed in the bottom left corner of the LCD display.

Auto focus and be turned back on by pressing **FOCUS** button a second time.

Setting Up the Firewire Digital Camera Interface

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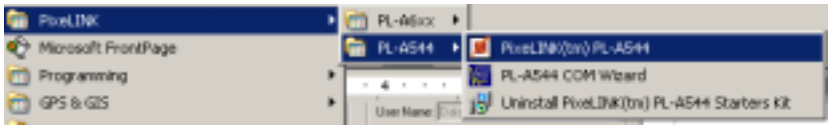
Overview

The ROMDAS for Windows direct digitising is done using an IEEE 1394 Firewire connection. For older systems with analog cameras it is necessary to use an Analog-Firewire converter. This section describes the installation and setup of the Pixelink system which is used for this purpose.

Installing Drivers

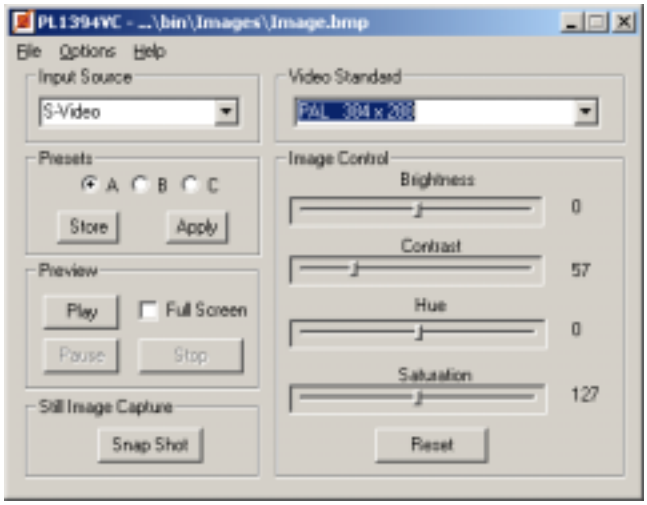
The Pixelink hardware is provided with a driver and setup disk. You will need to install these drivers and setup software - PL-A544StartersKit.exe.

After installation you must run the Pixellinl PL-544 software that will be available in your Programs menu to install the correct options for your setup.



Pixelink Options

The Pixelink options should be set to those shown below.



If there are any problems with the device you will need to check its installation in the Windows device manager as shown below. If the device is working correctly but is still not recognised by ROMDAS, contact info@romdas.com for support.

Mounting the Video Camera

Overview

The camera can either be installed in the enclosure mounted on the vehicle or in the vehicle with the suction mount. Installing the video camera to the enclosure consists of placing the camera on the inside of the enclosure, testing the camera, sealing the enclosure, and mounting the enclosure on the vehicle.

Installing the Camera on the Suction Mount

The Camera Suction Mount can be attached to any flat (or slightly curved) non-porous surface, which makes it possible to mount the Camera Suction Mount in many positions on a vehicle both inside or out (if mounted outside a safety strap is recommended). The mounting point surface needs to be free of vibrations. It can be fixed either vertically or horizontally. It can handle Camera's up to 1.5 kg in weight. The Camera Suction Mount fastens to the reversible camera plate, which enables the camera to be mounted above or below the Camera Suction Mount.

Generally the inside of the car windscreen is the best mounting point..

Instructions:

1. Remove the blue protective cap from the suction pad.
2. Make sure both the suction pad and surface are clean.
3. Press the suction pad firmly onto the surface and quickly pump the blue pump knob until the red line around the blue pump knob disappears
4. Attach Camera onto mount and adjust to the required position. Always keep the camera as close as possible to the suction pad for maximum stability.
5. It is normal that the vacuum decreases after a period of time, periodically check and re-pump if the red line reappears.
6. To remove the suction mount, remove the camera first, then lift-

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up rubber lug on suction pad.

Optionally if no suitable mounting surface can be found the supplied universal clamp can be used instead of the sunction mount. This can be attached to any tubes, boards etc between 13mm and 55mm.

Installing the Camera in the Enclosure

- Before the camera is inserted in the enclosure **CLEAN THE INSIDE OF THE GLASS LENS**. Once the camera is installed there should be no need to open the enclosure again.
- Check the camera foam to ensure that it is still in good condition and will hold the camera in place.

Testing

Before sealing the enclosure, the camera **MUST** be tested.

- Connect the 10 m S-Video and power cables to the enclosure
- Connect the remote control to the socket at the end of the remote cable
- Connect the power to the power distribution box

Using the remote, turn on the camera. If the camera does not turn on, check the power supply and connections.

Connect the 10 m S-Video cable to the VCR or video capture card. The camera image should be displayed.

Sealing the Enclosure

Once the camera has been tested it can be installed to the enclosure for sealing. Carefully place the camera into the dense foam and place the packing foam around it. Place a thin bead of silicon around the edge of the enclosure lid. Screw the lid into place.

Attaching Enclosure to the Base Plate

Using the supplied bolts, attach the enclosure to the base plate having applied locktite to the bolts beforehand.

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NOTE: Do not use longer bolts as these may damage the camera in the enclosure.

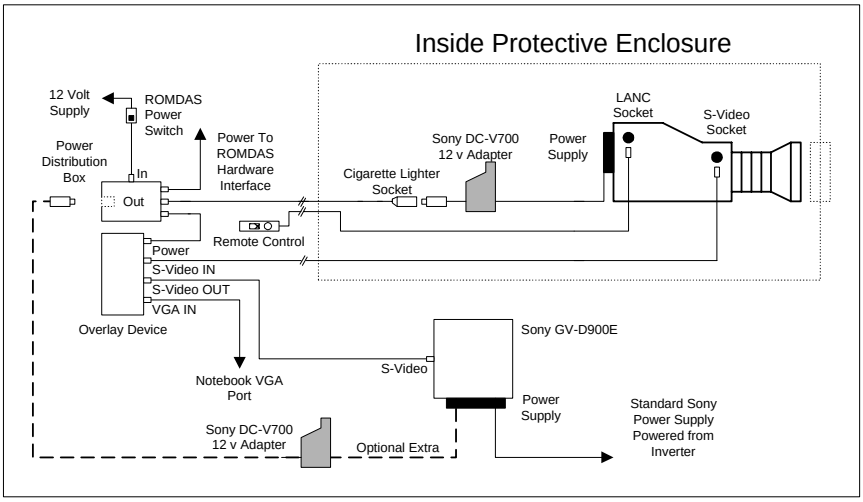
Mounting to the Vehicle

The base plate should be mounted to the vehicle roof rack, and the camera angled do ensure that the appropriate data are being viewed. For example, if recording the roadside the camera should be on a slight angle.

Setting Up the Overlay Device

Overview

The overlay device is used with analog cameras to superimpose the key survey data on the video image. The connections of the device is as shown below. There are two versions of the device in use, and the installation instructions are provided for each.



Video System with Overlay Device

Connections

The connections are as follows:

- Connect the overlay device power plug to a socket on the power distribution box.
- Connect the S-Video cable from the protective enclosure to the S-Video IN socket on the overlay device.
- Connect an S-Video cable from the overlay device S-Video OUT to:
  (a) the VCR S-Video socket if a VCR is used
  (b) the video capture card S-Video socket if direct digitising is used
  (c) the ROMDAS video 'splitter' if both VCR and direct digitising are used. Connect the video splitter cables to the VCR and the video capture card.
- Connect the overlay device cable from the VGA IN port to the notebook external VGA port.

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Coriogen Overlay Setup

The first time the system is used you will need to set up the following options which then are saved. The unit can then be usually used without any further adjustments. Select the following items from the sub-menus:

Overlay Menu:

- Signal Type – selecting the video input. Select CVid or SVid (Composite or S-Video) with ROMDAS you will generally using the S-Video signal type.
- Mode Set to Overlay

Advanced Menu:

- Video Standard – PAL or NTSC. Select PAL or NTSC depending upon the standard for the camera used.

After these are set you should run the AutoSet function so that the unit knows the size of the incoming computer image. You can then use arrow keys to fine tune the horizontal and vertical size as well as the position.

Save all settings by using the STORE button on the remote control or holding down MENU and FREEZE on the front panel for about two seconds (both confirmed by high pitch beep). These settings will now set whenever the unit is turned on.

Vinegen Overlay Setup

Press the **OVERLAY** button on the remote control. At this point the video image will be overlaid on the screen.

To refine the settings, start the ROMDAS roughness survey with the reduced screen option set to Y. This will see the standard screen replaced by a blank screen with lines of data on a coloured background. The video screen will show the image from the camera and the data from the ROMDAS survey.

It may be necessary to perform the following adjustments to improve the clarity of the image:

- The overlaid text may not be at the top of the display. To reposition it press the A/B button and the ‘Position’ arrow keys to locate the image at the appropriate location.
- The screen can be resized using the “Size” and “Position” controls.
- If the text is too blurred or too skeletal use the “KEY LEVEL” + and - keys to adjust the picture of the text. These buttons change the level of the colours cut out from the overlay. Using the - key will bring back the darker areas and the + key will cut them out.
- The “FILTER” button on the remote switches between two filters. One is high resolution with flicker and the other is low resolution

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with no flicker.

- The “FREEZE” button will freeze the display image. To unfreeze the image press the button again. This option should not be used with ROMDAS.
- The “FADE” button will fade the computer image in and out. When pressed once the light on the “FADE” light on the MultiGen2 will come on and the computer image will fade out. To fade in again just press the “FADE” button again. To change the length of this fading period use the “FADE TIME” + and - keys. This option should not be used with ROMDAS.

Setting Up the Firewire Analog Camera Interface

Overview

The ROMDAS direct digitising is done using an IEEE 1394 Firewire connection. For older systems with analog cameras it is necessary to use an Analog-Firewire converter. This section describes the installation and setup of the Pixelink system which is used for this purpose.

Installing Drivers

The Pixelink hardware is provided with a driver and setup disk. You will need to install these drivers and setup software - PL-A544StartersKit.exe.

After installation you must run the Pixellinl PL-544 software that will be available in your Programs menu to install the correct options for your setup.

Pixelink Options

The Pixelink options should be set to those shown below.

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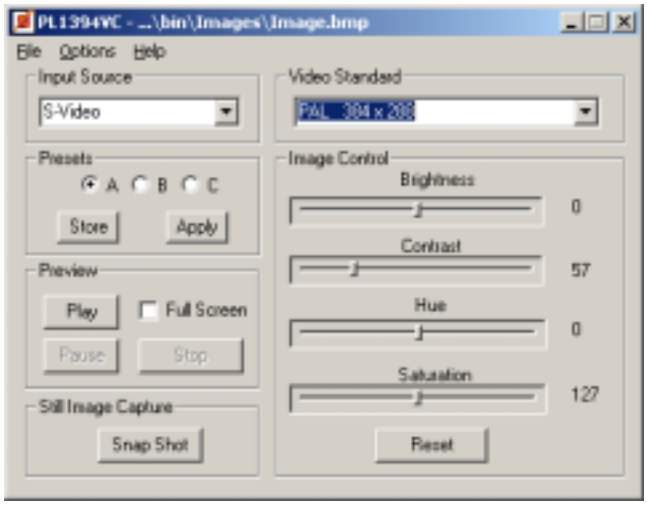

If there are any problems with the device you will need to check its installation in the Windows device manager as shown below. If the device is working correctly but is still not recognised by ROMDAS, contact info@romdas.com for support.

Setting Up the Firewire Digital Camera Interface

Overview

The ROMDAS direct digitising is done using an IEEE 1394 Firewire connection. For older systems with analog cameras it is necessary to use an Analog-Firewire converter. This section describes the installation and setup of the Pixelink system which is used for this purpose.

Installing Firewire Card

If the laptop doesn't already have a IEEE Firewire port then the PCMCIA Firewire Card supplied with your ROMDAS Video logging system will need to be used as follows.

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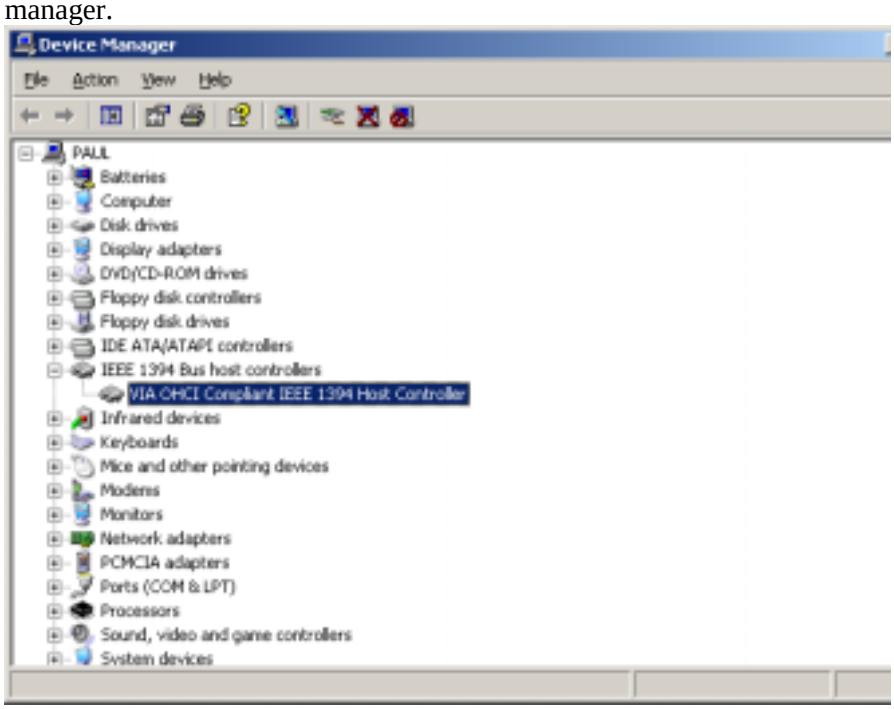
Insert Fire-wire card into any PCMCIA slot on the computer. Windows has plug and play support for the Firewire 1394 standard from WIN98 Second Edition onwards. Firewire card Installation can be checked under the IEEE 1394 Bus host controllers entry in the Windows device manager.



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Appendix F: Installing GPS Receivers and Gyroscope

Trimble Pocket Pathfinder GPS Receiver 269
Trimble PRO XR/XRS GPS Receiver 273
Garmin 12XL GPS Receiver 275
KVH Heading Gyroscope 279

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Trimble Pocket Pathfinder GPS Receiver

Components

The Trimble Pocket Pathfinder (PF) GPS receiver contains the following components:

- GPS Receiver
- Antenna
- Communications and Power Cable
- GPS 12V Power Supply
- RS-232 Extension Cable
- Adhesive Velcro

Installation

- Connect the antenna to the receiver
- Connect the **GREY** RS-232 plug to the RS-232 socket on the receiver. This plug is labelled GPS and has the black power plug coming from it. **UNDER NO CIRCUMSTANCES CAN THIS END OF THE CABLE BE CONNECTED TO THE COMPUTER. THE COMPUTER WILL BE DAMAGED**.
- Connect the power plug to the GPS power box socket
- Connect the 12V cigarette lighter on the power box to a

Example of Installation of Receiver and Connection of GPS Cable

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12V supply.

The receiver needs to be positioned so that the antenna can have a clear view of the sky. It is common to run the antenna through an open window, although it is better to drill a small hole in the vehicle and pass the cable through the hole. This will minimise the potential for damage to the cable.

Once the cable has been positioned, the double-sided Velcro should be affixed to the GPS receiver and the vehicle to keep the receiver out of the way. Ideally, the light should be in view.

The RS-232 cable should be connected to the computer, using the extension cable if necessary.

Setting up the Receiver

The PathFinder Pocket can be configured and tested using the GPS PathFinder Controller software. It can be found on the ROMDAS CD under menu[31]:

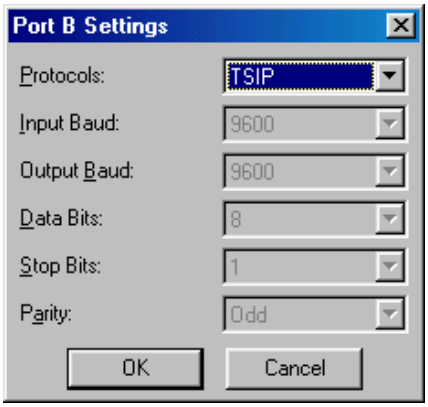
Software Extras|GPS|Trimble PocketPathfinder Control

When the software is started the screen to the right is shown (v 1.3). It is necessary to set the communications port to the appropriate value given the connections for the computer. The default is COM1.

For use with ROMDAS select:

Settings|Port B Settings

The **Protocols** should be set to **TSIP** (see bottom, right). This enables the data to be logged using the **Trimble TSIP** option of ROMDAS.



[31] Updates are available from www.trimble.com/gis.

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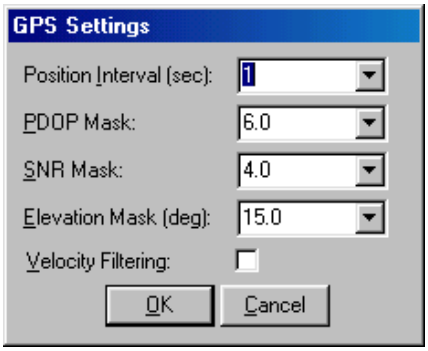
Optional Settings

The **Settings** menu contains a number of additional options for setting up the Pocket Pathfinder. These should be modified with care.

The following options are available under the **Settings|GPS Settings** menu:



- **Position Interval:** Specifies the frequency at which positions are stored. This needs to be set equal to or less than the "GPS Data Sampling Frequency" setting in the ROMDAS GPS Setup menu. The default value of 1 should therefore not be changed except in exceptional circumstances.

The following settings would normally be controlled directly form ROMDAS in the **Trimble Settings** option. See Section 11.5

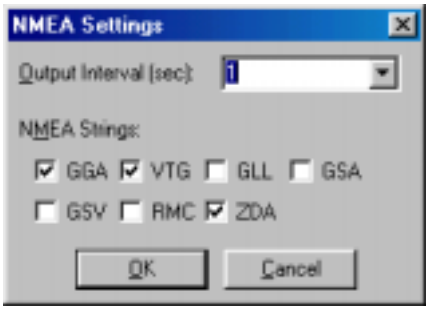
- **PDOP Mask:** Position Dilution of Precision (PDOP) is a measure of the satellite geometry. The lower the PDOP value, the more accurate the GPS positions. The PDOP mask is set to esure that only data of the required accuracy is collected. If the PDOP exceeds the configured mask the reciever stops logging positions. The recommended PDOP mask is 6.

- **SNR Mask:** Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to the background noise. Accuracy degrades as the signal strength decreases. You can configure the SNR mask on your datalogger to log only GPS positions below a certain SNR value.

  Note: PDOP and SNR act in opposite directions: greater accuracy is achieved with low PDOP and high SNR.

- **Elevation Mask:** This option is critical if you are wanting to differentially correct your data with a local base station. If it is set too low your reciever may use satillites which are are not visible to, or usable by , the base station, making it impossible to correct the data you have logged. If the elevation mask is set too high, it will unnecessarily reduce satellite availability. It should be set higher the further away you are from the base station.

The following options are available under the **Settings|NMEA Settings** menu:



- **Output Interval (sec):** Specifies the frequency at which positions are stored. Needs to be set equal to or less

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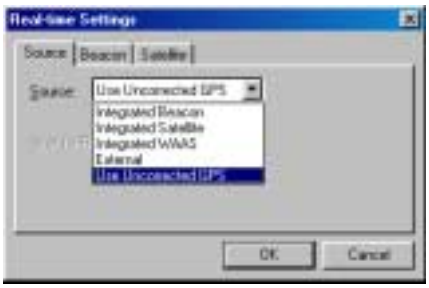
than the "GPS Data Sampling Frequency" setting in the ROMDAS GPS Setup menu.

- **NMEA Sentences:** The Pocket Pathfinder can output the following NMEA strings:
  - GPGGA
  - GPSA
  - GPVTG
  - GPRMC
  - GPZDA

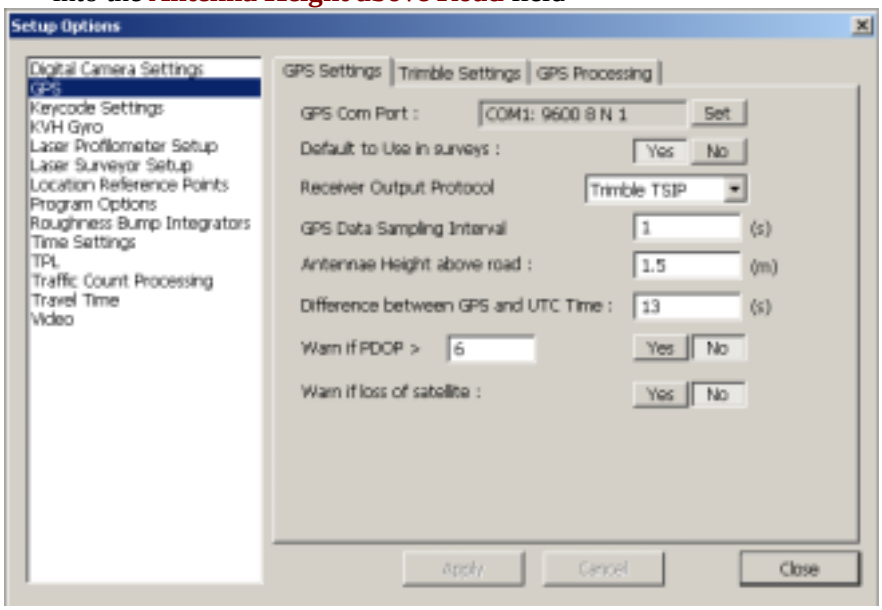
The **Settings|Real-time Settings** are used for real-time differential corrections. When selected, the screen to the right is given which lists the real time correction options.



The **Settings|Port A** settings refer to the settings for the Real Time Differential correction port. These are only applicable if you have the optional Real Time source splitter cable and have set up for one of the Real Time options above.

Setting up ROMDAS

- Select **Setup|Options|GPS Settings**
- Select the appropriate COM Port
- Set the Receiver Type to **Trimble TSIP**
- Measure height of Antenna above the road surface and enter value into the **Antenna Height above Road** field



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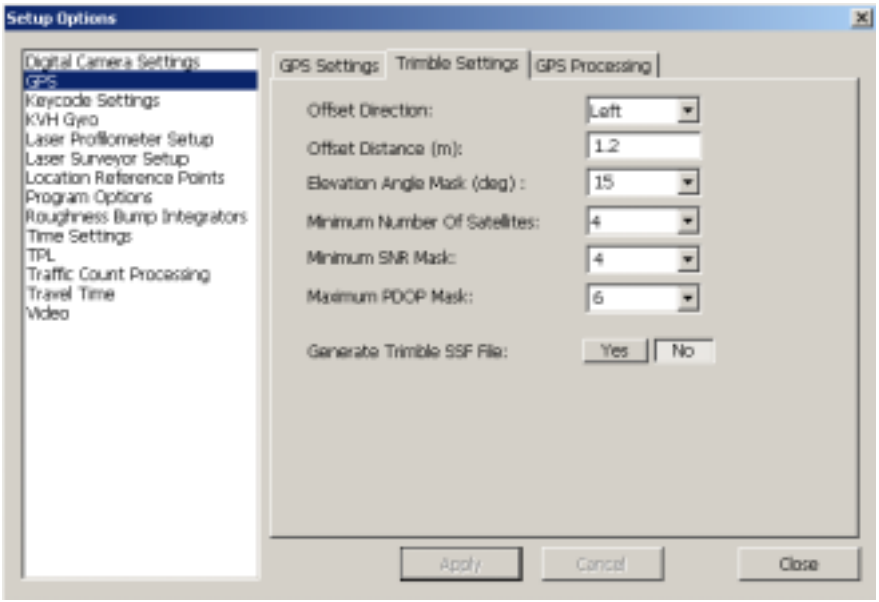
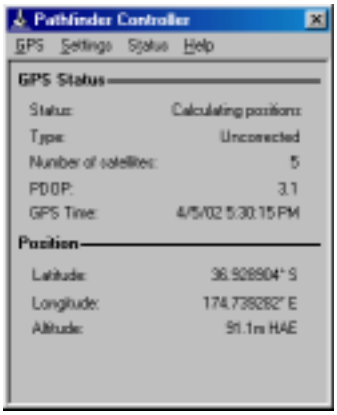


Testing

The PathFinder Controller software can be used to test the GPS reciver by using the **GPS|Connect** option. The data to the right will be displayed.



Please note if your reciever has not been used for a while or was last used in another part of the world it will not have the current almanac data and may take up to 30 mins until it can initialise and get a GPS fix.

Trimble PRO XR/XRS GPS Receiver

Components

The Trimble PRO XR/XRS Pathfinder GPS receivers contain the following components:

- GPS Receiver
- Antenna
- Communications and Power Cable
- GPS 12V Power Supply
- RS-232 Extension Cable

Installation

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- Connect the antenna to the receiver on the BNC connector
- Connect the RS-232 plug to the RS-232 socket on the data / power cable attached to Port B on the receiver. The yellow TSC1 Data logger does not need to be used when using ROMDAS in TSIP mode.

Connections on PRO XRS

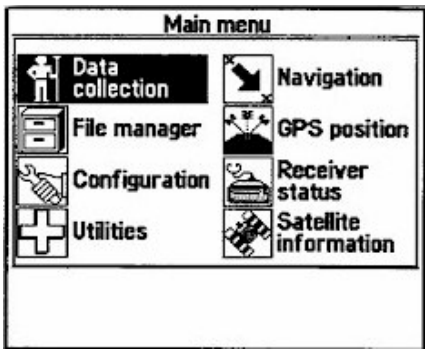
The receiver needs to be positioned so that the antenna can have a clear view of the sky. It is common to run the antenna through an open window, although it is better to drill a small hole in the vehicle and pass the cable through the hole. This will minimise the potential for damage to the cable.

Once the cable has been positioned, the double-sided Velcro should be affixed to the GPS receiver and the vehicle to keep the receiver out of the way. Ideally, the status lights should be in view.

Setting up the Receiver

The receiver will need to be configured before first use with the TSC1 Data logger connected to Port B instead of the computer running ROMDAS.

When the software is started the screen to the right is shown. It is necessary to set the communications port to the appropriate value given the connections for the computer. The default is COM1.



For use with ROMDAS select:

Configuration|Com Options

The **Protocols** should be set to **TSIP**. This enables the data to be logged using the ROMDAS TSIP option allowing direct control of the receiver from the ROMDAS software.

Setting up ROMDAS

See Section 11.5 on GPS settings. The **Receiver Output Protocol** should be set to **Trimble TSIP** as below.

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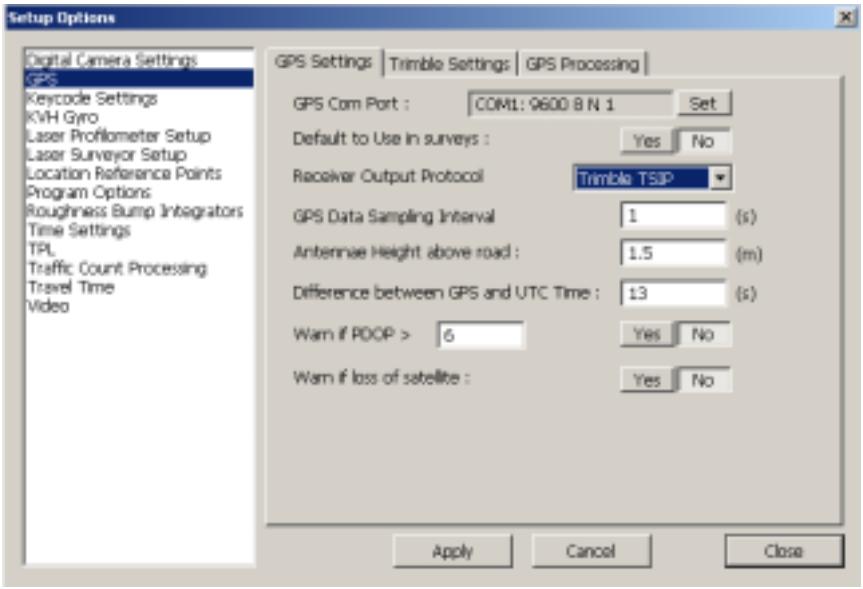

Garmin 12XL GPS Receiver

Components

The Garmin 12XL GPS receiver contains the following components:

- GPS Receiver
- External antenna GA 27 low profile antenna with 8' cable and magnetic/suction mount to attach to roof of ROMDAS vehicle - P/N 010-10052-03
- A combined Cigarette Lighter Adapter and PC interface cable to supply power in vehicle and interface to ROMDAS data collection computer RS232 port - P/N 010-10165-00

Installation

- Connect the antenna to the receiver
- Open the rubber plug at the rear of the receiver
- Connect the power and communications cable to the plug
- Connect the 12V cigarette lighter on the power box to a 12V supply.

The receiver needs to be positioned so that the antenna can have a clear

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view of the sky. There are two options for this:

- The Garmin mounting kit can be used to hold the antenna against the inside of the window.
- Alternatively, run the antenna through an open window and use the magnetic mount to hold it on the roof. It is better to drill a small hole in the vehicle and pass the cable through the hole. This will minimise the potential for damage to the cable.

Once the cable has been positioned, the double-sided Velcro should be affixed to the GPS receiver and the vehicle to keep the receiver out of the way. Ideally, the screen should be in view. Alternatively, a custom car-mount kit is available to hold the receiver (see to the right)

Optional Car Mount Kit

The RS-232 cable should be connected to the computer, using the extension cable if necessary.

Setting up the Receiver

When you turn the GARMIN GPS receiver on a welcome page will appear for a few seconds while the unit conducts a self-test, followed by various other of the five primary pages depending on satellite availability.

The output baud rate of the GARMIN needs to be set to match the ROMDAS GPS COM port baud rate setting in the ROMDAS Setup Options (see below).

The GARMIN's five primary pages are:

- Satellite Page
- Position Page
- Map Page
- Navigation Page
- Main Menu Page

You can scroll between these pages using either the **PAGE** or the **QUIT** keys.

To set up for ROMDAS we need to select the **Main Menu** Page.

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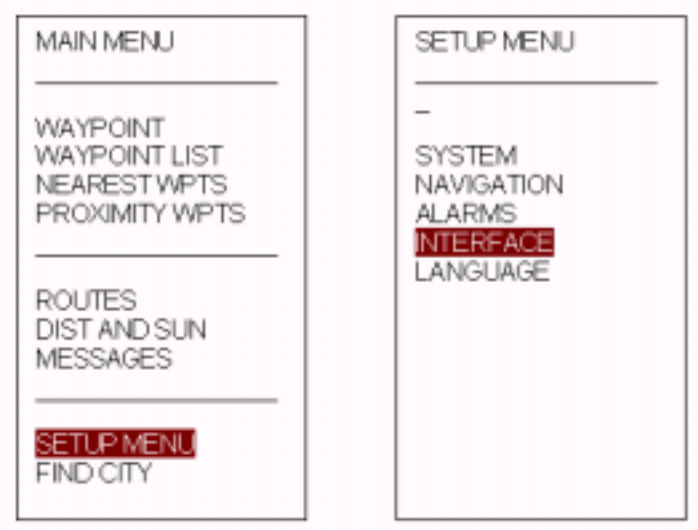
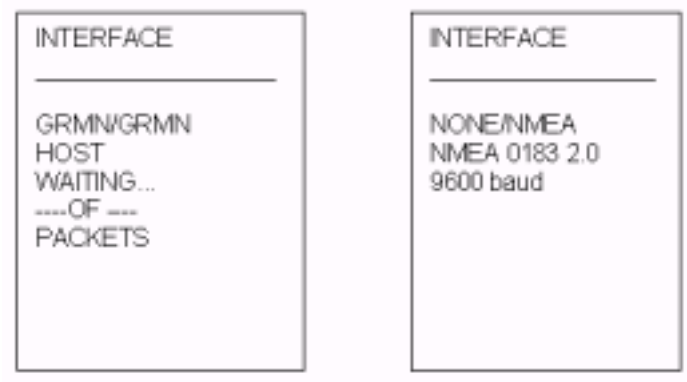


Using the up and down arrow keys and **Enter** key select **Setup Menu** and then **Interface**.



The INTERFACE page lets you specify the formats for connecting to external devices. There are six options:

- GRMN / GRMN (default)
- None / None
- RTCM / None
- RTCM / NMEA
- NMEA / NMEA
- None / NMEA

Each option lists - **Input Option / Output Options**.

Any of the last three options with **NMEA** as the output will work with ROMDAS.

When one of the NMEA output options is selected you will then need to set the NMEA format The following NMEA formats are supported by the GARMIN 12XL:

- NMEA 180
- NMEA 182

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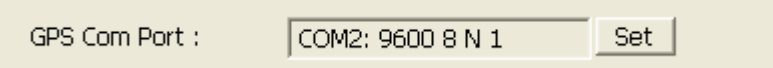
- NMEA 183 version 1.5
- NMEA 183 version 2.0

ROMDAS only recognises the **NMEA 183 version 2.0** format. The following NMEA 0183 version 2.0 sentences are output by the GARMIN 12XL: GPGGA, GPRMC, GPGSV, GPRMB, GPRMC, GPRTE, and GPWPL.

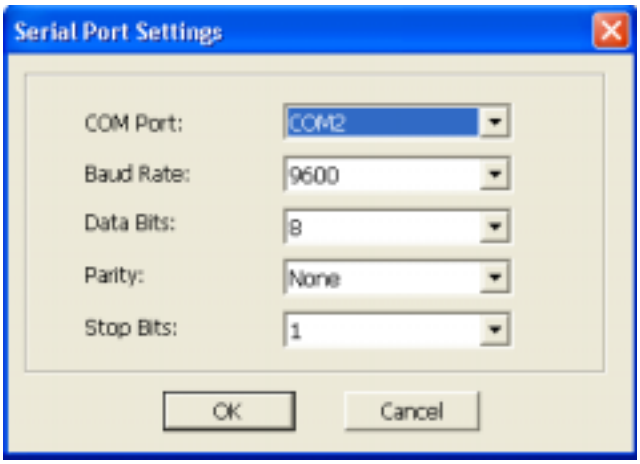
Setting up ROMDAS

The **baud rate** on the GARMIN defaults to 4800 while the ROMDAS default is 9600. All other COM port settings are not setable on the GARMIN and should remain at the defaults in ROMDAS.

- Select **Setup|Options|GPS**



- The **Set** button next to the **GPS Com Port** edit box will bring up the dialog below
- Check that the settings are as shown below



First Fix

If there has been memory loss or the receiver has been moved over 1000km with the power off the unit will typically take 3 –5 minutes to acquire its first position in Autolocate mode (the default). **YOU MUST BE STATIONARY FOR THIS TO WORK.** You can speed up this process by using the **Select Country from List** option from the **Initialisation Prompt**.

When the unit is turned on and the **WELCOME** page is replaced by the **SATELLITE** page, the **Initialisation Prompt** may automatically appear if the receiver needs initialization. If the **Initialisation Prompt** has not appeared from the **Satellite** page press the **Enter** key.

From the **Initialisation Prompt** choose **1. SELECT COUNTRY FROM LIST** and select the appropriate country.

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If the **Initialisation Prompt** ever appears after you have initialized the receiver (due to the antenna's view of satellites being obstructed) select the **3. NO RE-INIT** option with the arrow keypad and press **ENTER**

Testing

The unit should be tested as described in Section 3.14.

KVH Heading Gyroscope

Components

The KVH heading gyroscope has the following components:

- Gyroscope
- Base Plate
- Communications Cable
- Mounting Screws

Installation

A suitable position needs to be found in the vehicle for the gyroscope. Since the gyroscope does not require any operator intervention once installed, it may be installed in an area with limited accessibility such as under a seat. The gyroscope output is proportional to temperature and therefore the gyroscope should be mounted in an area that has a relatively constant temperature. Therefore avoid areas of direct sunlight, heaters or air-condition outlets etc. The gyroscope should not be removed from the base plate provided as this acts as a heat sink unless it is bolted directly to a metal surface of at least 0.05 m^2.

The gyroscope should be mounted as parallel as possible to the normal horizontal axis of the vehicle *i.e.* as level as possible. It should be installed with the directional arrow pointing forward in the direction of travel. It should not be mounted within 300 mm of any strong magnetic field or in areas of high vibration.

Once a suitable position has been established the following is done:

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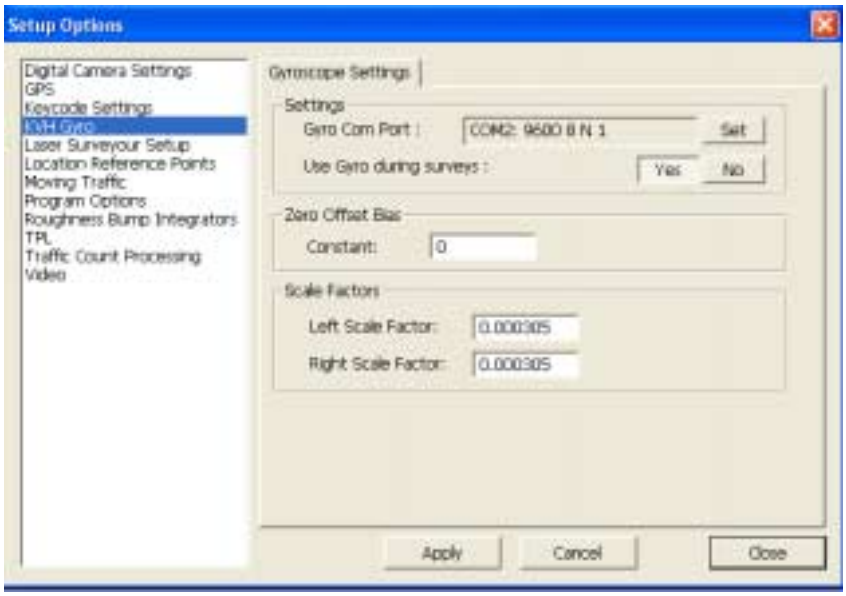
- Attach the gyroscope to the mounting plate
- Connect the gyroscope cable and tighten the two screws on the cable housing to the gyroscope
- Position the mounting plate as described above
- Ensure that the arrow adjacent to the cable connection is pointing to the front of the vehicle
- Mark the position of the four corner holes in the mounting plate on the vehicle floor
- Remove the mounting plate and gyroscope
- Drill holes in the vehicle corresponding to the corner holes
- Install the mounting plate and gyroscope
- Run the gyroscope cable to the data collection computer

Setting Up the Gyroscope

- Select **Setup|Options|Heading Gyroscope|Gyrocope Settings**
- Enter the Gyroscope COM port number
- Confirm the settings are for 9600 8 N 1
- Set the **Use Gyro Positioning Instrument in Surveys** to **Yes**. You will need to enter the password if this is the first time activated and the software is not in Testmode.



When any gyroscope is stationary there will be a bias drift which is a function of temperature. At a fixed temperature it can be in the range of 2 to 4 degrees/h. The calibration consists of establishing a bias correction factor for this drift.

- Ensure that the gyroscope is at the typical operating temperature for the survey vehicle. It should powered up for at least 5 minutes to stabilize the temperature
- Select **Setup|Calibrate|Calibrate Gyroscope|Gyro Autobias**
- With the gyroscope stationary, run an autobias test for 30 seconds

Record the bias correction factor and the temperature

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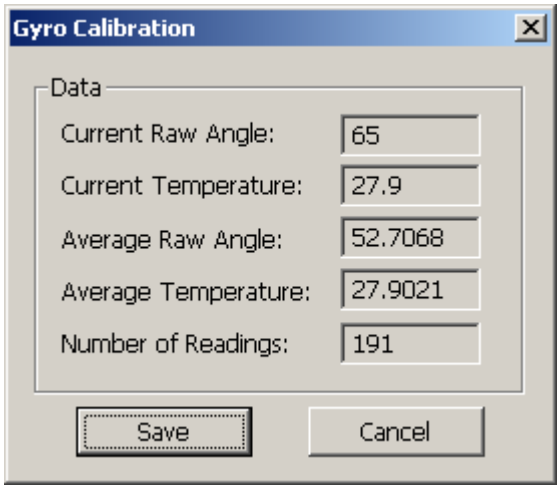
The 'Test Gyroscope' option is used to test the gyroscope.

- Ensure that the vehicle is stationary and on a level surface
- Connect the power to the gyroscope and the gyroscope to the data logging computer
- Select **Setup|Test Instruments|Test Gyroscope**
- Select **Start** to commence the gyroscope test.

The display will be as shown below. With the gyroscope motionless, the rate should be < 0.2 degrees/second and the angle < 0.5 degrees. If either of these criteria are not met, run the gyroscope autobias calibration as described above.



Testing the Gyroscope

Once the calibration is done the gyroscope should be tested.

- Ensure that the vehicle is stationary and on a level surface
- Connect the power to the gyroscope and the gyroscope to the data logging computer
- Select **Setup|Test Instruments|Test Gyroscope**
- Select **Start** to commence the gyroscope test.

The display will be as shown below. With the gyroscope motionless, the rate should be < 0.2 degrees/second and the angle < 0.5 degrees. If either of these criteria are not met, run the gyroscope autobias calibration as described above.

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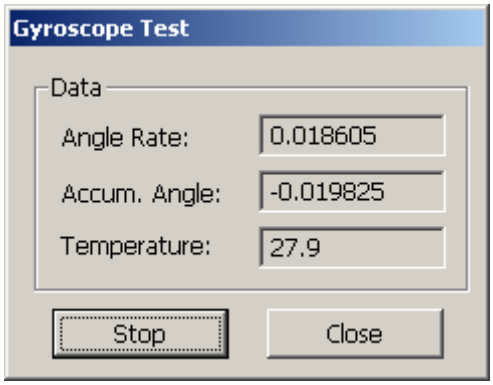

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Appendix G: Programming the Rating Keyboard

Rating Keyboards

The rating keyboard works alongside standard keyboards, or as a standalone keyboard. It is designed to simplify keyboard rating by allowing for a dedicated keyboard with the rows corresponding to up to 5 different types of distresses, the columns 4 different levels of severity for each distress. Alternatively, the keys can be assigned to different inventory items, or anything that can be visually recorded.

Note: The 58 and 20 key keyboards cannot be programmed using a notebook's keyboard. You must use a keyboard from a desktop computer.

The keyboard comes with a key puller. This enables you to remove the plastic caps on the keys and to label the key. Pre-printed cardboard cutouts are provided for this.

Installing the Rating Keyboard

- Turn off the computer.
- Plug the rating keyboard into the notebook computer.
- Plug the external keyboard to the rating keyboard. Alternatively, you can use a desktop computer and plug the rating keyboard into the computer and the computer's keyboard to the rating keyboard.
- Turn on the computer and ensure that the external keyboard works.

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Installing the Rating Keyboard

It is necessary to have an external keyboard available for programming the rating keyboard.

Turn off the computer.

1. Plug the rating keyboard into the notebook computer.
2. Plug the external keyboard to the rating keyboard. Alternatively, you can use a desktop computer and plug the rating keyboard into the computer and the computer's keyboard to the rating keyboard.
3. Turn on the computer and ensure that the external keyboard works.

Programming the Rating Keyboard

1. Decide upon the distresses—or any other keycode events—to be assigned to the rating keyboard.
2. Decide upon the levels of severities to be used.
3. Create a ROMDAS keycode event file with these distresses and severities
4. Slide the program switch on the right side of the rating keyboard to the program position (a red indicator will be visible to the left of the switch). **NOTE**: The red *or* green layer indicator light on the rating keyboard will blink, which lets you know that you are programming.
5. Tap on the rating keyboard the key you want to program. **NOTE**: The red or green layer indicator light will double flash.
6. Type on the external keyboard the key corresponding to the ROMDAS event key you want to program. For example, if the bottom row was to be assigned to cracking and from left to right was to be low, medium, high and extreme severities, using the example above, the letter C would be assigned to the bottom left, D to the second key, E to the third key and F to the bottom right key.
7. When the key has been entered, tap the key on the rating keyboard again. **NOTE**: The red or green layer indicator light will blink.
8. Repeat steps 5 to 7 until all the keys have been programmed. Slide the program switch down to the run position. The keyboard is ready to use.
9. Test the keyboard from the MS-DOS prompt by pressing the individual keys. The letter corresponding to the ROMDAS event should be displayed.

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Appendix H: Quality Assurance Forms

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This appendix contains the following forms:

E012 - Form 1

DMI and Roughness Calibration Log

This form is used when calibrating the roughness meter.

E012 - Form 2

TPL Calibration Log

This form is used when calibrating the TPL

E012 - Form 3

Pre-survey Check List

This form is completed before the survey commences

E012 - Form 4

Daily Survey Check List

This form is completed at the start of each day.

E012 - Form 5

Survey Road List

This form is used during the survey.

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Procedure:	**E012 - FORM 1**
Title:	**DMI AND ROUGHNESS CALIBRATION LOG**
Version:	**1.21**
Date of Last Revision:	**27/11/00**

Date: _____ **Vehicle:** _____ **Operator:** _____ **Tyre Pressure:** _____ **Date of Last Tyre Balance:** _____

DMI Calibration Site: _____ **Nominal Length (m):** _____

	Run 1	Run 2	Run 3	Run 4	Run 5
Calibration Factors by Run Number:					

Calibration Site Number	Roughness Calibration Results For Each Run									
	Run 1		Run 2		Run 3		Run 4		Run 5	
	Speed	Rough.	Speed	Rough.	Speed	Rough.	Speed	Rough.	Speed	Rough.
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Minimum of three runs for each speed. Check that sufficient runs have been performed using BETA statistic

Roughness Calibration Equation: _____ **Speed Range (km/h):** _____

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Procedure:	**E012 - FORM 2**
Title:	**TPL Calibration Log**
Version:	**1.21**
Date of Last Revision:	**24/01/01**

TPL Validation

Date: _____ **Vehicle:** _____ **Operator:** _____

Number of Sensors: _____ **Software Version:** _____ **TPL Constant:** _____ **TPL Slope:** _____ **Fixed Target Distance:** _____

Distance between Sensors: **5 - 6** _____ **10 – 11** _____ **15 - 16** _____ **20 - 21** _____ **25 - 26** _____

Run CREATE CALIBRATION DATA Option in ROMDAS _____ **Data Analysed With Excel Template** _____ **All Sensors With S. Error < 1 mm (append results)** _____ **Checked Sensor Numbering to Confirm 1-30 With 1 at Kerb** _____

TPL Settings

	TPL Sensor Numbering	Straight-Edge			Pseudo-Ruts			Error Corrections			
		Distance to Check	Left WP Length	Right WP Length	Low Point 1	High Point	Low Point 2	Max. Min. Elev.	Incr. Diff.	Correct O Elev.	Replace 0
Checked (Y/N):											
Value:	**N/A**										

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Procedure:	**E012 - FORM 3**
Title:	**Pre-Survey Check List**
Version:	**1.21**
Date of Last Revision:	**27/11/00**

Date: _____ **Vehicle:** _____ **Operator:** _____ **Survey:** _____

ROMDAS Survey Equipment

	Basic System	Roughness	Video Tape	Video Direct	TPL	Keyboard	GPS	GPS Gyro	GPS Laser
To Be Used in Survey (Y/N):									
Instrument Installed									
Check Power									
Spares:	Computer x 1 Interface x 1 Fuses x 5 Serial Cable x 2 Odo Cable x 3 DMI x 1 Floppy Disks	BI Wire x 5 BI Cable x 3 BI x 1	Tapes Cables	Computer x 1 CDs Cables	Sensor x 5	Keyboard			Serial Cable

Vehicle

	Engine Oil	Tyre Pressure	Tyre Balances	Spare Tyre	Survey Sign	Fuel Level			
Checked (Y/N):									

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Procedure:	**E012 - FORM 4**
Title:	**ROMDAS Daily Pre-Survey Check List**
Version:	**2**
Date of Last Revision:	**27/11/00**

Survey: _____ Client: _____

Date	Tyre Pressure Set to Standard Pressure	Fuel Tank Full	ROMDAS Battery Recharged Overnight	ROMDAS Battery Connected	Bump Integrator Cable Checked	Video Camera Installed Securely with Lens Cleaned	Video Cables Connected and Set to Auto-Focus	Start Vehicle	Power Up Inverters and Check Power to Video and Computer	Turn on ROMDAS and Ensure Lights are On

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Procedure:	**E012 - FORM 5**
Title:	**Survey Road List**
Version:	**2**
Date of Last Revision:	**27/11/00**

Survey: _____ Client: _____

Date	Road ID	Road Description	User Defined Field 1	User Defined Field 2	User Defined Field 3	Starting From	Ending At	Length (km)	Problem (Chain-age)	Done (Y/N)

Note: If problems are encountered record the chainage where they arose and a brief description on the subsequent line. Use multiple lines if more than one problem arises in a run.

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